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**PAUL WEIR COMPANY**

**MINING ENGINEERS**

20 NORTH WACKER DRIVE

CHICAGO, ILLINOIS 60606

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# AN
# ECONOMIC FEASIBILITY STUDY
# OF
# COAL DESULFURIZATION

VOLUME I

A Study for the
Division of Air Pollution
Public Health Service
U.S. Department of Health, Education and Welfare

Contract No. PH 86-65-29

by

Paul Weir Company, Inc.
20 North Wacker Drive
Chicago, Illinois 60606

October, 1965

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# ECONOMIC FEASIBILITY STUDY

# OF

# COAL DESULFURIZATION

## SECTION 1.0 Introduction

### 1.1 Object and Scope of Report

Under the Clean Air Act (Public Law 88-206, 88th Congress), the U.S. Department of Health, Education and Welfare is charged with the responsibility of expediting research into the desulfurization of fuels. The Act provides for the letting of contracts to complement research activities performed directly by the Public Health Service of the Department as well as by other organizations under research grants.

Under contract to the Public Health Service, through the Division of Air Pollution, the Paul Weir Company has investigated the feasibility of reducing the sulfur content of coals by generally known coal preparation methods together with known costs through case studies. This has been under Contract No. PH 86-65-29, dated December 15, 1964.

By "desulfurization" in this study, is meant the removal or lowering of the sulfur content of American coals through known methods of crushing, washing, and various processes other than changing the solid nature of coal, such as through chemical decomposition into gaseous and liquid products. This study is not involved with the removal of sulfur from flue gases.

Since the main source of sulfur dioxide air pollution from coal is the result of its use as "steam" coal, this study largely concerns itself with United States steam coals as distinct from coals used for metallurgical or coking purposes.

Work under this contract involved a study of the production, distribution and end use of bituminous and lignitic coals; a study of the proximate analyses of the major coal beds in the United States; a study of the sulfur forms in these major coal beds; an estimate of the reserves and location of high sulfur coal beds; case studies of current coal preparation practices in preparing steam coals including current costs and suggested methods of coal preparation, using the most modern available equipment together with an estimate of costs for such treatment based upon a 1,000 ton per hour capacity plant.

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## 1.2 Acknowledgements

Information for this study and report comes from many sources. In addition to literature and statistical data research, discussions were held with many of the leaders in the coal industry involved in the mining, preparation and use of coal as well as research groups and universities. A partial list of references is given in Section 6.0. Others are listed on the various tables, as they occur.

Information from the U.S. Bureau of Mines, published and unpublished data, was freely drawn upon as well as verbal discussions with Bureau personnel involved in this area of work. Numerous coal companies willingly gave test and operating data of vital importance.

The Paul Weir Company project engineer for this study was Mr. Raymond E. Zimmerman, a Vice President of the Company. He was assisted in the collection and preparing of data for the report by other company personnel, particularly Mr. George H. Roman. The guidance of Dr. Clayton G. Ball, President of the Paul Weir Company, is gratefully acknowledged.

Throughout the study, research and preparation of this report, close liaison has been kept with responsible personnel of the Division of Air Pollution, Public Health Service, and frequent conferences and progress reports were made. The Paul Weir Company worked through Mr. Paul W. Spaite, Deputy Chief of the Engineering R&D Section, Laboratory of Engineering and Physical Sciences, Division of Air Pollution, who is directly involved in the supervision of this contract, and Dr. J. H. Ludwig, Chief, Engineering and Physical Sciences. The advice of Dr. F. A. Rohrman, Staff Advisor to the Division of Air Pollution, was helpful at these joint conferences. The cooperation of all these gentlemen is gratefully acknowledged.

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## SECTION 2.0 Summary

2.1 Of the 435,000,000 tons of bituminous and lignite coal consumed in the United States in 1964, more than half was consumed by electric utilities for power generation. It has been estimated that by 1970, approximately 600,000,000 tons will be consumed of which at least 64 percent will be used by electric utilities.

There will be a gradual decline in coal used for household and allied uses and but a moderate increase in coal for coke making. Eventually, (beyond 1970), there will be a gradual increase in the uses of coal, assuming an economic breakthrough for gasification and production of liquid fuels.

2.2 The largest consuming region for coal is the East-North Central or Great Lakes region. Other large consuming areas are the Middle Atlantic and South Atlantic. The United States is divided into 23 coal producing districts. All the major coal beds together with their proximate analyses and sulfur contents are listed in this report.

2.3 In order to narrow down the number of coal beds for detailed study, we have arbitrarily used 2 percent total sulfur as the lower limit. There are about 47 major coal beds whose sulfur content will run 2 percent or higher. The total estimated minable reserves of these high sulfur coals are estimated as 75 billion tons.

The largest proportion of these high sulfur coals are in the states of Ohio, Indiana, Illinois and West Kentucky, the producers shipping the bulk of these coals to electric utilities.

2.4 A detailed investigation was made through literature search, direct contact with the U.S. Bureau of Mines, universities and coal companies concerning the nature of the various coal beds, their location, quality and, particularly, sulfur distribution.

Our research shows that although there are considerable data on some coal beds, particularly in the Appalachian area, there is a serious lack of information, particularly sulfur distribution, for coals in the midwestern fields. This has been a handicap in this study since the midwestern fields are prime suppliers of high sulfur steam coals.

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2.5 Sulfur occurs in three forms, organic, sulfate and pyritic. The amount of sulfate sulfur is very small and is usually disregarded or added to the organic. Organic sulfur, which is inherent in the coal substance, cannot be removed by physical means. In some coals organic sulfur may in itself be over 2 percent.

Pyritic sulfur comes in many forms and particle sizes. The coarser particles are relatively easy to remove while some are so finely disseminated that a proportion could almost be classed as inherent.

There is no such thing as a standard sulfur content for each coal bed. The amount and variety of sulfur forms will vary in the same coal bed from one area to another. The sulfur will vary in different layers of the bed from top to bottom.

It is, therefore, difficult to draw conclusions as to potential sulfur reduction for even a single coal bed without further pinpointing the location as well.

Nevertheless, there are some areas where the coals appear to be more amenable to reducing sulfur and others where reduction may be quite limited. It was found, for example, that most Central Pennsylvania coal beds can by proper crushing and cleaning be reduced to a reasonable level. There are some midwestern coals, however, where even with fine grinding, the sulfur level cannot be greatly reduced.

Generally, the higher the total sulfur, the higher the pyritic content. Also, generally, the percentage of sulfur reduction is greater with high sulfur than with low sulfur coals.

2.6 The removal of pyrite involves crushing coal to liberate pyrite particles. In some cases crushing to 1-1/2 inches may suffice. In many other cases only extreme fine grinding will bring about liberation. This may be down to 30 mesh in size or even to 200 mesh.

Most coal cleaning processes make use of the specific gravity relationship between coal (which is lightweight) and rock or pyrite, which is heavier. "Float and sink" analyses at various specific gravities are made to determine a coal's "washability", that is, its ability to separate from its impurities without undue loss. Various types of equipment have been designed to simulate this specific gravity relationship in practice. All commercial processes use water as the medium or a mixture of sand or magnetite and water. The exception is froth flotation which is used to treat coal finer than 30 mesh and makes use of physical-

chemical reactions at the coal interface to separate coal from its impurities. However, even froth flotation uses water as the carrying medium. Air tables may be used, but are not efficient.

To date, there is no known economical method of separation while coal is in the dry state, although, a rough pyrite concentration can be made by air classifiers; this method holds promise.

2.7 Six case studies of existing preparation plants are presented together with their flow sheets and coal characteristics, and an estimate of their capital and operating costs. Using a separating density of 1.60 (common in steam coal cleaning plants), washing costs varied from $0.25 per ton to as high as $0.532 per ton of product. Costs were also estimated for washing these coals at 1.45 and 1.35 specific gravities. At these lower gravities, costs increase in proportion to coal yield loss and efficiency of separation.

In none of these plants is the coal crushed finer than 1-1/2 inches and, generally, they are over 3 inches. In none of the six cases did the sulfur drop below 2 percent at the 1.60 specific gravity separation.

In the six case studies, total costs f.o.b. mine in cents per million Btu at the 1.60 specific gravity separating point varied from a low of 13.5 to 17.7 cents. At the 1.35 specific gravity range, it varied from 18.4 to 22 cents.

Few if any of the existing coal preparation plants on steam coal are actually designed for maximum sulfur reduction. In fact, large tonnages of coal to electric utilities are not cleaned in any way and many plants do only a simple job of scalping off the larger pieces of rock.

2.8 For these reasons, submitted in this study are three proposed methods for cleaning coal that attempts to incorporate the most modern techniques consistent with costs and crushing the coal to acceptable limits for handling. One plan assumes rail or barge transportation and crushes the coal to minus 3/8 inches; another plan crushes the coal to minus 14 mesh for pipelining as a slurry; while another plan makes a final crushing at the power plant air classifiers and recleans the high sulfur fraction.

It is estimated that Plan "A", where the maximum product size is 3/8 inches, coal can be prepared for $0.487 per ton of product. Plan "B", where the coal is washed first at a preparation plant and pulverized and air classified at the power plant with part

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returned for rewashing, the preparation costs would be $0.532 per ton of product. Plan "C", where the coal is washed and crushed to 14 mesh and kept in a slurry suitable for pipelining, the preparation costs are estimated to be $0.416 per ton of product.

Although these preparation costs are somewhat higher than many preparation costs for steam coal, they are not higher than for coal prepared for metallurgical markets and, assuming $2.45 per ton for initial mining costs, the f.o.b. costs per million Btu range from 14.8 to 15.3 cents for 12,000 Btu per pound coal.

The actual sulfur levels achieved by any of these plans will depend upon the sulfur distribution in the particular coal seam. There is no data available on the effect of fine crushing of Illinois and West Kentucky coals, except one test made by Bituminous Coal Research on the Illinois No. 6 bed, and this particular coal did not show a sulfur liberation. Many other coals, however, can be reduced to below the 2.00 percent sulfur level by a combination of crushing and proper coal preparation techniques.

2.9 Although it is not the purpose of this study to investigate the possibilities of treating high pyritic content rejects from coal preparation plants, it is our belief that such study should be made to determine the most suitable method of concentrating pyrite itself and processing it for iron and sulfur recovery. A suggested process flow sheet is given, to show what might be accomplished by fluo solid roasting and reducing followed by magnetic separation and sulfuric acid recovery.

2.10 One of the results of this investigation is that it shows there are many gaps of information that have to be explored before a final feasibility study can be completed that would cover all the aspects of coal desulfurization by coal preparation methods. Some suggested fields of required investigation are:

(a) Investigation of the sulfur forms and distribution of all major high sulfur coal beds in the United States, including the effect of fine grinding for pyritic liberation.

(b) Test data on the cleanability or washability of these coals.

(c) Research into better methods of removing pyrite from coal other than by specific gravity separation, thus improving coal yield while at the same time eliminating pyrite.

(d) An investigation of the economics of recovering both iron and sulfur from high pyritic content coals.

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# SECTION 3.0 Project Analysis

## 3.1 Consumption of Coal in the United States by End Use

The U.S. Bureau of Mines divides the end use of coal into four major categories for statistical purposes. They are: Electric Utilities, Coke and Gas Plants, Retail Dealers and All Others.

Under Electric Utilities this includes all coal used by public and privately owned utility companies for the generation of electric power.

Coke and Gas Plants includes all coal carbonized for manufacture of coke, coal chemicals, water gas and other gasification processes. It does not include coal used for heating and other steam raising purposes around steel and chemical plants.

Retail Dealers includes basically all coal shipped to retail yards for sale to domestic (household) heating, apartment and office heating and small industrial users.

All Others includes coal used by larger industrial users, usually by direct shipment, and may be used for space heating, steam raising, cement mills, railroads and processing other than carbonizing. Some may be used for internal power generation.

The consumption of bituminous coal and lignite by the above categories is shown in Table No. 1 for the years 1959 through to 1964, and projected for the year 1970. Anthracite consumption, which is chiefly used for space heating, is also shown. In our desulfurization study, anthracite is not included, as American anthracite analyzes less than 1 percent total sulfur. None of the tonnages include export coal.

The significant conclusions reached in analyzing the statistics shown in Table No. 1 are:

1. The gradual and persistent increase in coal consumption in the United States, almost doubling in twelve years if the projections by various energy policy groups and economists are correct.

2. The rapid decline of coal used for household and allied users.

3. An only moderate increase in coal for coke and gas plants.

4. The considerable increase in the use of coal by electric utilities (estimated 64.2 percent of all coal used by 1970).

Table No. 1

Consumption of Coal in the United States by End Use
for 1959 - 1964 and Projected for 1970
(Thousands, Net Tons)(1)(2)

| End Use(4) | 1959 | 1960 | 1961 | 1962 | 1963 | 1964(5) | 1970(6) | |
|---|---|---|---|---|---|---|---|---|
| Electric Utilities | 165,788 | 173,882 | 179,629 | 190,833 | 209,038 | 226,000 | 381,600 | 64.2% |
| Coke and Gas Plants | 79,172 | 81,015 | 73,881 | 74,262 | 77,633 | 89,000 | 97,600 | 16.0 |
| Retail Dealers | 29,138 | 30,405 | 27,735 | 28,188 | 23,548 | 20,000 | 18,300 | 3.0 |
| All Others | 92,158 | 95,127 | 93,160 | 94,491 | 99,006 | 100,000 | 102,500 | 16.8 |
| Total (Bituminous & Lignite) | 366,256 | 380,429 | 374,405 | 387,774 | 409,225 | 435,000 | 600,000 | 100.0% |
| Anthracite(3) | 18,800 | 17,600 | 15,900 | 14,300 | 14,200 | 14,000 | 13,400 | - |

Notes:

(1) Source of information: (a) U.S.B.M.-1963 Minerals Year Book, Vol. II FUELS.
(b) U.S.B.M.-IC 8242 (1964) Summary of Energy Balances for U.S.
(c) U.S.B.M.-Mineral Market Reports-1959-60-61-62-63.
(d) U.S. Dept. Interior-Energy Policy Staff, 1963, Table 16.

(2) Coal consumption pertains to bituminous and lignite coals for U.S.A. only. Canada and other export countries not included.

(3) Anthracite shown for information. Bulk of all anthracite consumed is for space heating, with small percentages to electric utilities and iron and steel industry (sintering and pelletizing).

(4) End Use: (a) Electric Utilities - includes all public and privately owned utility companies.
(b) Coke & Gas Plants - includes all coal carbonized for manufacture of coke, coal chemicals, water gas and other gasification processes. Does not include coal used for heating and other steam raising purposes around steel and chemical plants.
(c) Retail Dealers - includes basically all coal shipped to retail yards for sale to domestic (household) heating, apartment and office heating, and small industrial users.
(d) All Others - includes coal used by industrial users for steam raising, space heating, processing other than carbonizing, cement mills, railroads, etc.

(5) 1964 data are preliminary. Official figures are not available. Used McGraw-Hill, Keystone, Jan. 1965.

(6) 1970 data are projected figures based primarily on source (1)(d) above for utilities and coke consumption and curve projections for other categories. Percent of consumption for utilities by 1970 is estimated to be 64.2 percent (77.7 percent by 1980). Coal for space heating is estimated to be only 3 percent of consumption by 1970.

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5. The gradual decline in the consumption of anthracite.

6. A slight increase in the use of coal for general industrial use other than power generation and coking.

It is believed that a longer projection will show even a higher percentage of bituminous coal and lignite will be used for power generation (in spite of or along with the increase in nuclear energy), and that an eventual "breakthrough" will result in the increased use of coal for gasification and the production of liquid fuels.

## 3.2 Consumption of Coal by Geographical Regions

The consumption of coal in the United States varies considerably in geographical areas. This is obviously the result of closeness to coal producing districts and/or oil or gas distribution as well as population density and industrial concentration.

The regions of coal consumption in the United States are outlined in a map of the United States in Exhibit A, which also shows the bituminous, lignite and anthracite coal fields. These regional areas are used by the U.S. Bureau of Mines and the Federal Power Commission in the compilation of their statistics.

The regions are: I, New England; II, Middle Atlantic; III, South Atlantic; IV East-North Central; V, West-North Central; VI, East-South Central; VII, West-South Central; VIII, Mountain; and IX, Pacific, including Alaska.

Table No. 2 shows the consumption of bituminous coal and lignite for these geographical regions by end use, for the years 1963, 1964 and projected 1970. The big consumers of coal are by far, East-North Central, Middle Atlantic and South Atlantic. These are highly industrialized areas near coal producing districts and with high population densities.

The East-North Central region, consisting of the states of Ohio, Indiana, Illinois, Michigan and Wisconsin, will consume more than twice as much coal as any other region by 1970. Unfortunately, as will be shown further on in this study, most of the coals consumed for steam raising purposes in this region, are high sulfur coals.

Although in terms of total tonnage, the amount of coal used in the West is small; the expected percentage increase shows particularly for Region VIII, the Mountain district, as a result of expected increases in coal production for utility purposes in that area.

Table No. 2 Consumption of Bituminous Coal & Lignite in the United States by End Use for Geographical Regions, Years 1963-1964 and Projected 1970
(Thousands, Net Tons)(1)

| | Region I New England | | | |
|---|---|---|---|---|
| | 1963 | 1964 | 1970 | 19 |
| Electric Utilities | 7,770 | 8,100 | 9,000 | 34, |
| Coke and Gas Plants | 472 | 470 | 400 | 26, |
| Retail Dealers | 807 | 800 | 400 | 1, |
| All Others | 1,475 | 1,600 | 2,200 | 17, |
| Total | 10,524 | 10,970 | 12,000 | 79, |

| | Region IV East North Central | | | |
|---|---|---|---|---|
| | 1963 | 1964 | 1970 | 19 |
| Electric Utilities | 78,944 | 81,650 | 145,000 | 13, |
| Coke and Gas Plants | 27,709 | 28,750 | 37,000 | |
| Retail Dealers | 14,222 | 14,600 | 9,700 | 2, |
| All Others | 43,548 | 45,100 | 46,300 | 6, |
| Total | 164,423 | 170,100 | 238,000 | 23, |

| | Region VII West South Central(2) | | | |
|---|---|---|---|---|
| | 1963 | 1964 | 1970 | 19 |
| Electric Utilities | 17 | 19 | 25 | 5, |
| Coke and Gas Plants | 616 | 645 | 740 | 2, |
| Retail Dealers | 37 | 37 | 35 | 1, |
| All Others | 132 | 139 | 200 | 1, |
| Total | 802 | 840 | 1,000 | 10, |

Regions:

| | | |
|---|---|---|
| I. | New England | Massachusetts, Connecticut, Maine, New Hampshire, Vermont, Rhod |
| II. | Middle Atlantic | New York, New Jersey, Pennsylvania. |
| III. | South Atlantic | Delaware & Maryland, District of Columbia, Virginia, West Virgi |
| IV. | East North Central | Ohio, Indiana, Illinois, Michigan, Wisconsin. |
| V. | West North Central | Minnesota, Iowa, Missouri, North & South Dakota, Nebraska & Kan |
| VI. | East South Central | Kentucky, Tennessee, Alabama, Mississippi. |
| VII. | West South Central | Arkansas, Louisiana, Oklahoma & Texas. |
| VIII. | Mountain | Colorado, Nevada, Utah & Idaho, Montana & Wyoming, New Mexico & |
| IX. | Pacific | California, Washington, Oregon, Alaska. |

Notes:

(1) 1963 figures are actual tonnages from U.S.B.M.-1963 Minerals Year Book.
1964 figures are preliminary. Official data not yet published.
1970 figures are estimates based on various sources used in Table No. 1 and combined end

(2) A Texas utility uses approximately one million tons of Texas lignite not shown in the st

End Use

**Region II**
**Middle Atlantic**

| 1963 | 1964 | 1970 |
|---|---|---|
| 34,300 | 36,200 | 50,000 |
| 26,138 | 27,640 | 33,000 |
| 1,357 | 1,260 | 1,000 |
| 17,697 | 18,900 | 21,000 |
| 79,492 | 84,000 | 105,000 |

**Region III**
**South Atlantic**

| 1963 | 1964 | 1970 |
|---|---|---|
| 35,977 | 37,490 | 76,000 |
| 9,044 | 9,290 | 10,100 |
| 3,203 | 3,300 | 2,300 |
| 15,628 | 16,280 | 17,600 |
| 63,852 | 66,360 | 106,000 |

**Region V**
**West North Central**

| 1963 | 1964 | 1970 |
|---|---|---|
| 13,179 | 13,885 | 23,175 |
| 776 | 780 | 860 |
| 2,602 | 2,673 | 2,000 |
| 6,685 | 7,022 | 9,465 |
| 23,242 | 24,360 | 35,500 |

**Region VI**
**East South Central**

| 1963 | 1964 | 1970 |
|---|---|---|
| 32,436 | 33,950 | 60,000 |
| 7,641 | 7,980 | 10,500 |
| 1,999 | 2,080 | 1,665 |
| 5,342 | 5,550 | 7,835 |
| 47,418 | 49,560 | 85,000 |

**Region VIII**
**Mountain**

| 1963 | 1964 | 1970 |
|---|---|---|
| 5,832 | 6,124 | 18,000 |
| 2,465 | 2,586 | 3,000 |
| 1,122 | 1,156 | 900 |
| 1,404 | 1,474 | 1,600 |
| 10,823 | 11,340 | 23,500 |

**Region IX**
**Pacific**

| 1963 | 1964 | 1970 |
|---|---|---|
| 336 | 378 | 400 |
| 1,653 | 1,852 | 2,000 |
| 326 | 363 | 300 |
| 1,058 | 1,187 | 1,300 |
| 3,373 | 3,780 | 4,000 |

re, Vermont, Rhode Island.

ginia, West Virginia, North Carolina, South Carolina, Georgia & Florida.

a, Nebraska & Kansas.

ing, New Mexico & Arizona.

and combined end use tonnages equal that shown in Table No. 1 for 1970.
t shown in the statistics.

PAUL WEIR COMPANY
20 NORTH WACKER DRIVE
CHICAGO 6, ILLINOIS

## 3.3 Distribution of Bituminous Coal and Lignite from Mining Districts of Origin to Regions of Consumption

In accordance with the Bituminous Coal Act of 1937, the United States coal producing areas are divided into 23 districts. The boundaries and locations of these districts are shown on a map of the United States together with the major coal fields, as Exhibit B. The definition of these districts are explained in Exhibit C.

It will be noted that although many districts are confined to a particular state, some cross state boundaries and even counties of a state. These districts were apparently formulated to conform to a combination of coal usage, war time administration, freight rates and other regulatory control as well as geographical location.

Alaska is part of District No. 23. District No. 5, which includes coal in the state of Michigan, is non-active as there are presently no coal producers in this state. District No. 6 includes only the "Panhandle" area of West Virginia.

Table No. 3 tabulates the distribution of bituminous coal and lignite from these various districts for the years 1963 (the last year available for complete statistics), and shows the destination of these coals to the nine regions previously described, as well as the four categories of end use. The total production from the various districts are also shown. Discrepancies in consumption may occur in this tabulation due to some uncertainties of orgin and distribution. For example, some coals along the seaboard may be used for bunker coal and some of the Great Lakes tonnage may be shipped to Canadian ports.

Basically, however, the pattern is consistent and shows where the bulk of coal production is distributed, its source, and how it is used.

## 3.4 Range of Proximate Analyses, Btu Values and Total Sulfur of the Major Coal Beds in the United States

Table No. 4 lists the major coal beds (or seams) in the United States. There are other beds of relatively minor significance or reserves. Also, local names for the same bed frequently occur in different districts or coal fields. The names for the most important producing beds are fairly well-established, however.

This table gives the range of proximate analyses (ash, volatile matter, fixed carbon) and total sulfur content on a dry basis; Btu values on an "as received" basis; total moisture of the sample as received

Table No. 3 Distribution of Bituminous Coal & Lignite from Mining Districts of Origin to Regions of Consumption and Their End Use for 1963
(Thousands, Net Tons)

| Geographic Region and End Use | | | Total(1) | 1 | 2 | 3&6 | 4 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| I. | New England | Electric Utilities | 7,770 | 2,657 | 123 | 1,686 | - | 216 | 3,088 | - |
| | | Coke and Gas Plants | 472 | - | 2 | 27 | - | 37 | 313 | - |
| | | Retail Dealers | 807 | 52 | 8 | 68 | - | 327 | 516 | - |
| | | All Others | 1,475 | 553 | 71 | 623 | - | 43 | 365 | - |
| | | Total | 10,524 | 3,262 | 194 | 2,404 | - | 623 | 4,282 | - |
| II. | Middle Atlantic | Electric Utilities | 34,300 | 12,002 | 8,358 | 12,856 | 256 | - | 828 | - |
| | | Coke and Gas Plants | 26,138 | 1,911 | 11,506 | 5,012 | - | 3,865 | 3,944 | - |
| | | Retail Dealers | 1,357 | 462 | 537 | 240 | 15 | 48 | 55 | - |
| | | All Others | 17,697 | 5,838 | 6,350 | 4,055 | 354 | 75 | 925 | - |
| | | Total | 79,492 | 20,213 | 26,751 | 22,163 | 625 | 3,988 | 5,757 | - |
| III. | South Atlantic | Electric Utilities | 35,977 | 3,207 | 389 | 7,025 | 927 | 962 | 20,979 | 1, |
| | | Coke and Gas Plants | 9,044 | - | 2,453 | 3,005 | - | 1,735 | 1,269 | - |
| | | Retail Dealers | 3,203 | 73 | 1,038 | 854 | 4 | 826 | 1,165 | - |
| | | All Others | 15,628 | 655 | 49 | 277 | 408 | 1,160 | 12,761 | - |
| | | Total | 63,852 | 3,935 | 3,929 | 11,161 | 1,339 | 4,683 | 36,174 | 1, |
| IV. | East North Central | Electric Utilities | 78,944 | 739 | 1,290 | 3,343 | 21,158 | 37 | 8,781 | 12, |
| | | Coke and Gas Plants | 27,709 | - | 3,983 | 306 | - | 8,805 | 13,669 | - |
| | | Retail Dealers | 14,222 | 19 | 76 | 243 | 1,695 | 1,367 | 6,399 | 1, |
| | | All Others | 43,548 | 273 | 303 | 1,222 | 10,100 | 1,412 | 12,366 | 1, |
| | | Total | 164,423 | 1,031 | 5,652 | 5,114 | 32,953 | 11,621 | 41,215 | 15, |
| V. | West North Central | Electric Utilities | 13,179 | - | 2 | 79 | 354 | 34 | 182 | |
| | | Coke and Gas Plants | 776 | - | - | - | - | 210 | 566 | - |
| | | Retail Dealers | 2,602 | - | - | 28 | 176 | 73 | 618 | |
| | | All Others | 6,685 | 19 | - | 56 | 260 | 244 | 454 | |
| | | Total | 23,242 | 19 | 2 | 163 | 790 | 561 | 1,820 | |
| VI. | East South Central | Electric Utilities | 32,436 | - | - | - | - | - | 6,815 | 16, |
| | | Coke and Gas Plants | 7,641 | - | - | - | - | 769 | 1,672 | |
| | | Retail Dealers | 1,999 | - | - | - | - | 12 | 1,049 | |
| | | All Others | 5,342 | - | - | - | - | 233 | 1,786 | 2, |
| | | Total | 47,418 | - | - | - | - | 1,014 | 11,322 | 18, |
| VII. | West South Central(3) | Electric Utilities | 17 | - | - | - | - | - | - | - |
| | | Coke and Gas Plants | 616 | - | - | - | - | - | - | - |
| | | Retail Dealers | 37 | - | - | - | - | - | - | |
| | | All Others | 132 | - | - | - | - | 1 | - | |
| | | Total | 802 | - | - | - | - | 1 | - | |
| VIII. | Mountain | Electric Utilities | 5,832 | - | - | - | - | - | - | - |
| | | Coke and Gas Plants | 2,465 | - | - | - | - | 50 | - | - |
| | | Retail Dealers | 1,122 | - | - | - | - | - | - | - |
| | | All Others | 1,404 | - | - | - | - | - | - | - |
| | | Total | 10,823 | - | - | - | - | 50 | - | - |

MINING DISTRICTS(2)

| 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Excl. Tex. 15(3) | 16 | 17 | 18 | 19 | 20 | 21 | 22&23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 216 | 3,088 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 37 | 313 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 327 ) | 516 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 43 | 365 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 623 | 4,282 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| - | 828 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3,865 | 3,944 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 48 | 55 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 75 | 925 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3,988 | 5,757 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 962 | 20,979 | 1,762 | - | - | - | 726 | - | - | - | - | - | - | - | - | - |
| 1,735 | 1,269 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 826 | 1,165 | - | - | - | - | 10 | - | - | - | - | - | - | - | - | - |
| 1,160 | 12,761 | - | - | - | - | 21 | - | - | - | - | - | - | - | - | - |
| 4,683 | 36,174 | 1,762 | - | - | - | 757 | - | - | - | - | - | - | - | - | - |
| 37 | 8,781 | 12,035 | 22,289 | 9,204 | - | - | - | - | - | - | - | - | - | - | - |
| 8,805 | 13,669 | - | 1,256 | - | - | - | - | - | - | - | - | - | - | - | - |
| 1,367 | 6,399 | 1,445 | 2,603 | 875 | - | - | - | - | - | - | - | - | - | - | - |
| 1,412 | 12,366 | 1,525 | 11,182 | 4,535 | - | - | - | - | - | - | - | - | - | - | - |
| 11,621 | 41,215 | 15,005 | 37,330 | 14,614 | - | - | - | - | - | - | - | - | - | - | - |
| 34 | 182 | 186 | 6,073 | 6 | 916 | - | - | 3,703 | - | - | - | 205 | - | 1,439 | - |
| 210 | 566 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 73 | 618 | 219 | 665 | 13 | 41 | 13 | 1 | 196 | - | 93 | - | 44 | 10 | 413 | 2 |
| 244 | 454 | 175 | 3,152 | 287 | 389 | - | - | 916 | - | - | - | 198 | - | 540 | - |
| 561 | 1,820 | 580 | 9,890 | 306 | 1,346 | 13 | 1 | 4,615 | - | 93 | - | 447 | 10 | 2,392 | 2 |
| - | 6,815 | 16,096 | 3,283 | - | - | 6,242 | - | - | - | - | - | - | - | - | - |
| 769 | 1,672 | 29 | - | - | - | 5,171 | - | - | - | - | - | - | - | - | - |
| 12 | 1,049 | 575 | 5 | - | - | 358 | - | - | - | - | - | - | - | - | - |
| 233 | 1,786 | 2,199 | 266 | - | - | 858 | - | - | - | - | - | - | - | - | - |
| 1,014 | 11,322 | 18,899 | 3,554 | - | - | 12,629 | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | 17 | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | 479 | 137 | - | - | - | - | - | - | - |
| - | - | 14 | 8 | - | - | - | - | 15 | - | - | - | - | - | - | - |
| 1 | - | 3 | - | - | - | - | 6 | 116 | - | - | - | - | - | - | - |
| 1 | - | 17 | 8 | - | - | - | 485 | 285 | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | 508 | 1,214 | 1,512 | 1,939 ) | - | - | - |
| 50 | - | - | - | - | - | - | 132 | - | - | 1,084 | - | - ) | 1,469 | - | - |
| - | - | - | - | - | - | - | - | - | 74 | 228 | 12 | 80 | 670 | - | - |
| - | - | - | - | - | - | - | - | - | 174 | 275 | 25 | 582 | 346 | - | - |
| 50 | - | - | - | - | - | - | 132 | - | 756 | 2,801 | 1,549 | 2,591 | 2,485 | - | - |

B

Table No. 3 (continued)

| Geographic Region and End Use | | Total(1) | 1 | 2 | 3&6 | 4 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| IX. Pacific | Electric Utilities | 336 | - | - | - | - | - | - |
| | Coke and Gas Plants | 1,653 | - | - | - | - | - | - |
| | Retail Dealers | 326 | - | - | - | - | - | - |
| | All Others | 1,058 | 4 | - | - | - | 4 | - |
| | Total | 3,373 | 4 | - | - | - | 4 | - |
| Total U.S.A. | Electric Utilities | 209,038 | 18,605 | 10,162 | 24,989 | 22,695 | 1,249 | 40,673 |
| | Coke and Gas Plants | 77,633 | 1,911 | 17,944 | 8,350 | - | 11,654 | 21,433 |
| | Retail Dealers | 23,548 | 1,963 | 1,659 | 1,433 | 1,890 | 2,653 | 9,802 |
| | All Others | 99,006 | 7,342 | 6,773 | 6,233 | 11,122 | 3,172 | 28,657 |
| | Total | 409,225 | 29,821 | 36,538 | 41,005 | 35,707 | 18,728 | 100,565 |

**Notes:**

(1) Totals are from U.S.B.M. Minerals Year Book 1963, Table 67.
(2) Districts of Origin are from U.S. Dept. Interior 1963 Distribution.
(3) Does not include Texas lignite for captive power use of about one million tons.
) Combined tonnage - not broken down between coke use and others.

A

MINING DISTRICTS(2)

| | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Excl. Tex. 15(3) | 16 | 17 | 18 | 19 | 20 | 21 | 22&23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | - | - | - | - | - | - | - | - | - | - | - | 34 | - | - | 336 |
| | - | - | - | - | - | - | - | - | - | 593 | - | - | 1,093 | - | - |
| | - | - | - | - | - | - | - | - | - | - | - | 1 | 220 | - | 481 |
| 4 | - | - | - | - | - | - | - | - | - | - | 3 | - | 381 | - | 252 |
| 4 | - | - | - | - | - | - | - | - | - | 593 | 3 | 35 | 1,694 | - | 1,069 |
| 49 | 40,673 | 30,079 | 31,645 | 9,210 | 916 | 6,968 | - | 3,720 | 508 | 1,214 | 1,512 | 2,168 | - | 1,439 | 336 |
| 54 | 21,433 | 29 | 1,256 | - | - | 5,171 | 611 | 137 | - | 1,677 | - | - | 1,469 | - | - |
| 53 | 9,802 | 2,253 | 3,281 | 888 | 41 | 381 | 1 | 211 | 74 | 321 | 12 | 125 | 900 | 413 | 483 |
| 72 | 28,657 | 3,902 | 14,600 | 4,822 | 389 | 879 | 6 | 1,032 | 174 | 275 | 28 | 780 | 727 | 540 | 252 |
| 28 | 100,565 | 36,263 | 50,782 | 14,920 | 1,346 | 13,399 | 618 | 5,100 | 756 | 3,487 | 1,552 | 3,073 | 3,096 | 2,392 | 1,071 |

B

Table 4. Range of Total Sulphur and Proximate Analyses of Major Bituminous Coal Beds by Districts of Origin Consumed in the United States for Power and Steam Generation in Geographical Regions

Percent

| (1) Region No. | District of Origin | Name of Coal Beds | Moisture (Total) | Sulphur (Total) | Ash |
|---|---|---|---|---|---|
| I,II, III | No. 1 Central Pa, etc. | Lower Kittanning "B" | | | |
| | | Cambria County | 2.7- 3.2 | 0.9-5.3 | 8.0- 8.6 |
| | | Clearfield County | 2.5- 3.6 | 1.0-1.7 | 8.4- 9.3 |
| | | Somerset County | 3.3- 3.7 | 0.7-1.0 | 8.4- 8.8 |
| | | Middle Kittanning "C" | | | |
| | | Composite of 7 Counties | 2.1- 4.7 | 0.7-4.5 | 4.5-11.0 |
| | | Upper Kittanning "C" "C Prime" | | | |
| | | Cambria County | 1.7- 5.6 | 0.6-3.9 | 6.6-10.9 |
| | | Indiana County | 2.6- 3.5 | 0.9-3.0 | 5.7-10.3 |
| | | Lower Freeport "D" | | | |
| | | Cambria County | 1.9- 4.9 | 0.6-3.3 | 5.1-11.2 |
| | | Clearfield County | 1.9- 4.1 | 0.5-4.3 | 4.9-10.7 |
| | | Upper Freeport "E" | | | |
| | | Cambria County | 2.0- 4.5 | 0.7-3.2 | 5.4-11.3 |
| | | Somerset County | 2.1- 6.3 | 1.0-2.4 | 7.9-15.1 |
| | | Maryland County | 1.7- 5.3 | 0.8-4.2 | 5.3-14.1 |
| II, III, IV | No. 2 Western Pa. | Pittsburgh Seam | | | |
| | | Allegheny County | 2.0- 4.3 | 0.8-2.0 | 4.4- 8.8 |
| | | Westmoreland County | 2.0- 5.9 | 0.8-1.9 | 5.4-12.7 |
| | | Washington County | 1.1- 3.9 | 0.8-2.8 | 4.9- 9.6 |
| | | Greene County | 1.7- 3.7 | 0.8-3.9 | 4.2-10.8 |
| | | Brookeville Seam | | | |
| | | Butler County | 2.9- 3.5 | 2.4-6.0 | 9.1-16.1 |
| | | Mercer County | 4.6- 5.8 | 0.9-6.0 | 3.2- 9.7 |
| | | Clarion Seam | | | |
| | | Clarion County | 3.2- 4.8 | 0.9-6.3 | 5.8-11.7 |
| I, II, III IV | No. 3 & 6 Northern W.Va. & Panhandle (W.Va.) | Fairmount Area | | | |
| | | Sewickley Seam | 1.3- 4.3 | 1.6-4.2 | 8.6-10.0 |
| | | Pittsburgh Seam | 1.0- 5.7 | 0.9-4.8 | 5.6- 9.2 |
| | | Preston-Taylor Area | | | |
| | | Upper Freeport | 1.2- 4.7 | 0.7-2.2 | 4.8-13.0 |
| | | Bakerstown | 1.8- 4.1 | 0.6-3.9 | 4.7- 8.2 |
| | | Lower Kittanning | 2.3- 3.3 | 0.9-2.0 | 7.0-10.9 |
| | | Randolph-Barbour | | | |
| | | Pittsburgh | 1.4- 4.3 | 0.7-2.5 | 6.6- 7.6 |
| | | Red Stone | 1.5- 4.4 | 1.6-4.4 | 6.0- 9.8 |
| | | Webster-Gawley Area | | | |
| | | Sewell | 2.2- 3.2 | 0.5-0.8 | 5.1- 6.6 |
| | | Panhandle Area | | | |
| | | Pittsburgh No. 8 | 1.3- 5.0 | 2.7-5.0 | 7.9-10.7 |

A

| F 2) | Percent Dry Basis Ash | Volatile Matter | Fixed Carbon | BTU, As Received | Coal Rank (ASTM) | Notes |
|---|---|---|---|---|---|---|
| 3 | 8.0- 8.6 | 21.0-23.0 | 64.0-67.4 | 13,550-13,870 | Lvb | Analyses-U.S.B.M. 1957-1963 |
| 7 | 8.4- 9.3 | 23.2-24.0 | 64.2-67.0 | 13,590-13,600 | Mvb | |
| 0 | 8.4- 8.8 | 17.0-18.0 | 70.0-72.0 | 13,615-13,870 | Lvb | |
| 5 | 4.5-11.0 | 19.4-30.3 | 61.9-69.0 | 13,300-14,250 | Lv-Mvb | |
| 9 | 6.6-10.9 | 12.0-18.5 | 69.0-77.4 | 13,290-14,310 | Lvb | |
| 0 | 5.7-10.3 | 23.1-32.5 | 55.6-67.6 | 13,250-14,260 | Lv-Mvb | |
| 3 | 5.1-11.2 | 17.2-26.6 | 62.5-71.2 | 13,400-14,340 | Lvb | |
| 3 | 4.9-10.7 | 21.0-31.0 | 58.2-69.7 | 12,960-14,490 | Lv-Mvb | |
| 2 | 5.4-11.3 | 14.9-26.5 | 61.4-73.5 | 13,460-14,380 | Lv-Mvb | |
| 4 | 7.9-15.1 | 17.1-24.2 | 60.0-68.0 | 12,280-13,680 | Lvb | |
| 2 | 5.3-14.1 | 15.4-21.9 | 63.6-72.8 | 12,300-14,250 | Lvb | |
| 9 | 4.4- 8.8 | 32.7-38.6 | 53.4-59.4 | 12,800-14,160 | Hvab | |
| | 5.4-12.7 | 22.9-35.2 | 55.2-62.5 | 13,060-14,150 | Hvab | |
| | 4.9- 9.6 | 32.3-38.7 | 49.2-59.4 | 13,170-14,340 | Hvab | |
| | 4.2-10.8 | 33.0-36.4 | 52.2-57.3 | 13,040-14,140 | Hvab | |
| | 9.1-16.1 | 31.7-36.3 | 50.0-54.6 | 12,090-13,070 | Hvbb | |
| | 3.2- 9.7 | 34.6-40.7 | 48.3-54.8 | 12,630-13,610 | Hvbb | |
| | 5.8-11.7 | 34.7-39.8 | 46.4-54.8 | 12,560-13,680 | Hvab | |
| | 8.6-10.0 | 35.0-37.8 | 51.7-53.3 | 13,250-13,700 | Hvab | |
| | 5.6- 9.2 | 36.0-38.2 | 53.6-56.4 | 13,600-14,280 | Hvab | |
| | 4.8-13.0 | 24.2-31.7 | 53.7-65.7 | 13,200-14,700 | Mvb | |
| | 4.7- 8.2 | 15.4-28.7 | 65.6-73.2 | 13,000-14,800 | Lv-Mvb | |
| | 7.0-10.9 | 28.8-32.6 | 55.5-59.8 | 13,190-14,040 | Mvb | |
| | 6.6- 7.6 | 37.0-41.0 | 51.0-54.3 | 13,200-14,000 | Hvab | |
| | 6.0- 9.8 | 35.2-38.0 | 54.0-54.6 | 13,590-13,985 | Hvab | |
| | 5.1- 6.6 | 26.6-32.8 | 61.4-64.6 | 14,210-14,400 | Mvb | |
| | 7.9-10.7 | 37.0-41.7 | 50.5-52.5 | 12,620-13,853 | Hvab | |

B

14

Table 4. (continued)

| (1) Region No. | District of Origin | Name of Coal Beds | Percent Dry: Moisture (Total) | Sulphur (Total) | Ash | Vola Mat |
|---|---|---|---|---|---|---|
| III, IV | No. 4 Ohio | Pittsburgh No. 8 (Harrison & Belmont) | 3.2- 6.8 | 2.3-5.6 | 7.5-11.5 | 37.6 |
| | | Lower Kittanning (No. 5 Coal) | 3.3- 8.5 | 2.3-5.8 | 7.6- 8.6 | 36.6 |
| | | Middle Kittanning (No. 6 Coal) | 4.4- 8.2 | 1.5-4.8 | 6.6- 8.8 | 35.1 |
| | | Upper Freeport (No. 7 Coal) | 2.9- 6.7 | 2.2-5.7 | 8.2-10.5 | 35.3 |
| | | Meigs Creek (No. 9 Coal) | 3.9- 4.5 | 2.3-6.4 | 11.5-15.2 | 36.3 |
| III, IV | No. 7 Southern W.Va. and part of Virginia. Basically the Pocahontas Field. | Pocahontas No. 3 | 0.5- 1.0 | 0.4-0.7 | 3.5- 7.0 | 15.0 |
| | | Pocahontas No. 4 | 0.5- 1.0 | 0.4-0.8 | 4.0- 7.0 | 15.0 |
| | | Sewell | 0.5- 1.5 | 0.4-0.9 | 2.0- 5.0 | 13.0 |
| | | Beckley | 1.0- 3.0 | 0.5-1.0 | 2.0- 5.7 | 16.0 |
| I, III, IV, VI | No. 8 West Central W.Va. Southwest W.Va. Western part of Va. East Kentucky Northeast Tennessee North Carolina | Kanawha Field (W.Va.) | | | | |
| | | Winifrede Seam | 1.4- 3.9 | 0.5-1.0 | 3.8- 4.4 | 27.9 |
| | | Dorothy | 1.9- 2.4 | 0.5-0.6 | 4.1- 6.4 | 34.0 |
| | | Eagle | 1.0- 2.1 | 0.7-0.8 | 3.1- 5.7 | 28.9 |
| | | No. 2 Gas | 0.3- 2.8 | 0.5-2.1 | 3.2- 9.5 | 28.0 |
| | | Logan Field (W.Va.) | | | | |
| | | Cedar Grove | 1.1- 3.6 | 0.5-2.8 | 3.4- 9.2 | 31.1 |
| | | Eagle (see above) | | | | |
| | | Alma | 1.5- 3.9 | 0.6-1.8 | 2.0- 5.0 | 35.0 |
| | | Williamson Field (W.Va.) | | | | |
| | | Cedar Grove (see above) | | | | |
| | | Pond Creek (see No. 2 Gas above) | | | | |
| | | Harlan Field (Ky.) | | | | |
| | | Harlan Seam | 2.0- 5.0 | 0.5-1.4 | 2.0- 8.1 | 35.0 |
| | | High Splint | 3.1- 4.6 | 0.5-0.8 | 3.4- 4.6 | 35.0 |
| | | Darby (No. 5) | 1.3- 3.5 | 0.6-0.7 | 3.1- 3.9 | 35.5 |
| | | So. Appalachian (Ky.) | | | | |
| | | Creech Seam | 1.7- 4.8 | 0.7-1.7 | 2.1- 6.9 | 27.6 |
| | | Kellioka | 1.4- 2.7 | 0.3-0.7 | 1.8- 4.7 | 34.0 |
| | | Wallins | 2.7- 3.7 | 0.6-1.0 | 3.0- 5.5 | 37.8 |
| | | Leatherwood Seam | 2.8- 3.9 | 0.6-0.8 | 3.4- 7.2 | 37.4 |
| | | Hazard Field (Ky.) | | | | |
| | | Hazard No. 4 | 2.9- 4.1 | 0.6-1.0 | 3.1- 7.4 | 35.6 |
| | | Hazard No. 6 | 2.7- 6.4 | 0.6-0.8 | 3.3- 6.9 | 32.6 |
| | | Hazard No. 7 (analysis similar to No. 4) | | | | |
| | | Hazard No. 9 | 3.4- 5.9 | 1.6-2.8 | 4.8- 6.7 | 35.0 |
| | | N.E. Kentucky Field (Ky.) | | | | |
| | | Elkhorn No. 1 | 2.7- 4.0 | 0.8-1.0 | 5.0- 6.2 | 38.8 |
| | | Elkhorn No. 2 | 2.6- 4.7 | 0.7-2.0 | 3.7- 5.8 | 38.3 |
| | | Elkhorn No. 3 | 2.0- 4.1 | 0.6-0.9 | 3.2- 6.0 | 34.9 |

A

| Percent Dry Basis | | | | | |
|---|---|---|---|---|---|
| Ash | Volatile Matter | Fixed Carbon | BTU, As Received | Coal Rank (ASTM) | Notes |
| 7.5-11.5 | 37.6-41.7 | 50.0-51.9 | 12,550-13,160 | Hvab | District No. 5 is in the State of Michigan. No coal is mined in this district. |
| 7.6- 8.6 | 36.6-40.5 | 46.4-49.0 | 12,053-13,158 | Hvbb | |
| 6.6- 8.8 | 35.1-39.6 | 46.2-51.1 | 11,800-13,680 | Hvbb | |
| 8.2-10.5 | 35.3-37.1 | 50.2-52.8 | 12,610-12,800 | Hvbb | |
| 11.5-15.2 | 36.3-38.9 | 45.7-46.9 | 12,062-12,228 | Hvbb | |
| 3.5- 7.0 | 15.0-23.0 | 70.0-81.0 | 14,000-15,000 | Lvb | Less than 10 percent of the coals in this district are used for steam purposes. About 30 percent is exported; the balance for coke making and some retail. All seams "smokeless" and low-sulphur. |
| 4.0- 7.0 | 15.0-23.0 | 70.0-81.0 | 14,000-15,000 | Lvb | |
| 2.0- 5.0 | 13.0-23.0 | 72.0-81.0 | 14,000-15,000 | Lvb | |
| 2.0- 5.7 | 16.0-19.0 | 73.0-81.0 | 14,000-15,200 | Lvb | |
| 3.8- 4.4 | 27.9-35.3 | 53.7-63.3 | 13,340-14,470 | Hvab | This is the major coal producing district in the United States, mining over 100 million tons per year of which 40 percent is used for utility, 28 percent for other steam raising, and 21 percent for coking. |
| 4.1- 6.4 | 34.0-36.6 | 58.9-59.6 | 14,300-14,700 | Hvab | |
| 3.1- 5.7 | 28.9-35.0 | 60.1-64.6 | 14,410-14,960 | Hvab | |
| 3.2- 9.5 | 28.0-40.0 | 55.4-65.1 | 13,120-14,640 | Hvab | |
| 3.4- 9.2 | 31.1-41.4 | 50.9-61.6 | 13,290-14,990 | Hvab | |
| 2.0- 5.0 | 35.0-41.0 | 53.4-59.6 | 14,080-14,660 | Hvab | |
| 2.0- 8.1 | 35.0-39.3 | 51.5-58.0 | 12,840-14,380 | Hvab | |
| 3.4- 4.6 | 35.0-36.3 | 53.8-56.9 | 13,210-14,100 | Hvab | |
| 3.1- 3.9 | 35.5-37.5 | 58.1-60.5 | 13,720-14,424 | Hvab | |
| 2.1- 6.9 | 27.6-39.1 | 53.2-57.7 | 13,630-14,320 | Hvab | |
| 1.8- 4.7 | 34.0-37.8 | 52.7-62.8 | 13,900-14,620 | Hvab | See Harlan County |
| 3.0- 5.5 | 37.8-40.4 | 53.7-55.3 | 13,490-13,880 | Hvab | |
| 3.4- 7.2 | 37.4-39.3 | 53.4-59.1 | 13,380-14,480 | Hvab | |
| 3.1- 7.4 | 35.6-38.4 | 53.9-58.2 | 13,200-14,100 | Hvab | |
| 3.3- 6.9 | 32.6-38.0 | 52.9-59.0 | 12,750-14,350 | Hvab | |
| 4.8- 6.7 | 35.0-37.9 | 50.7-53.9 | 12,875-13,780 | Hvab | |
| 5.0- 6.2 | 38.8-41.0 | 53.9-56.0 | 13,860-14,000 | Hvab | These coals are excellent coking coals. |
| 3.7- 5.8 | 38.3-42.7 | 50.3-58.0 | 13,800-14,000 | Hvab | |
| 3.2- 6.0 | 34.5-37.2 | 57.3-60.2 | 13,710-14,300 | Hvab | |



B

Table 4. (continued)

| (1) Region No. | District of Origin | Name of Coal Beds | Moisture (Total) | Sulphur (Total) | Ash | Percent Dr Vo M |
|---|---|---|---|---|---|---|
| I, III, IV, VI | No. 8 (continued) | **Tennessee** | | | | |
| | | **So. Appalachian Field** | | | | |
| | | Coal Creek Seam | 1.3- 3.7 | 0.8-2.0 | 3.4- 7.5 | 33. |
| | | Pee Wee | 3.1- 4.0 | 0.6-1.0 | 3.4- 7.0 | 35. |
| | | Red Ash | 3.2- 5.2 | 0.9-1.4 | 4.5-10.0 | 35. |
| | | **Jellico Field** | | | | |
| | | Jellico Seam | 2.9- 7.6 | 0.8-2.5 | 2.0- 8.6 | 33. |
| | | Blue Gem | 3.4- 5.7 | 0.7-2.2 | 1.2- 5.8 | 36. |
| | | **Lafollette-Pork Mt.** | | | | |
| | | Big Mary Seam | 0.8- 1.5 | 2.0-4.4 | 9.0-14.0 | 36. |
| | | **Virginia** | | | | |
| | | **S.W. Virginia Field** | | | | |
| | | Clintwood Seam | 0.9- 2.2 | 0.7-1.1 | 3.5- 5.0 | 31. |
| | | Imboden | 1.8- 3.1 | 0.6-0.9 | 2.0-10.0 | 33. |
| | | Jewell | 1.0- 2.5 | 0.7-0.8 | 2.4- 6.0 | 21. |
| | | Lower Banner (Cary) | 1.0- 4.0 | 0.7-1.8 | 5.0-11.0 | 21. |
| | | Splash Dam | 1.0- 3.5 | 0.7-1.0 | 5.2- 7.5 | 32. |
| | | Taggart | 2.0- 4.2 | 0.3-0.8 | 1.7- 4.6 | 34. |
| | | Upper Banner | 1.8- 2.2 | 0.5-0.7 | 4.7- 5.8 | 31. |
| IV, VI | No. 9 West Kentucky | No. 6 Seam | 9.8-16.0 | 1.9-3.4 | 2.8-10.0 | 35. |
| | | No. 9 Seam | 4.5- 6.2 | 2.8-4.4 | 9.0-10.5 | 39. |
| | | No. 11 Seam | 8.4-12.7 | 3.2-4.7 | 0.1- 9.0 | 42. |
| | | No. 12 Seam | 4.5-13.4 | 1.1-3.8 | 7.0-13.4 | 38. |
| | | No. 14 Seam | 7.0-11.0 | 2.0-4.7 | 7.5-11.0 | 38. |
| IV, V, VI | No. 10 Illinois | **Northern Illinois** | | | | |
| | | Colchester No. 2 | 15.4-17.1 | 1.6-5.2 | 5.9-10.4 | 40. |
| | | Herrin No. 6 | 11.9-14.0 | 3.5-5.4 | 9.2-12.8 | 40. |
| | | Danville No. 7 | 14.2-15.3 | 3.2-4.7 | 12.1-16.7 | 41. |
| | | **Western Illinois** | | | | |
| | | Rock Island No. 1 | 11.2-16.6 | 4.8-6.5 | 9.6-12.1 | 40. |
| | | No. 5 Seam | 14.5-15.4 | 2.7-4.0 | 11.0-13.0 | 41. |
| | | No. 6 Seam | 15.0-18.3 | 3.5-6.4 | 10.6-13.8 | 39. |
| | | **Springfield** | | | | |
| | | No. 5 Seam | 13.4-15.3 | 3.3-4.9 | 10.7-13.0 | 41. |
| | | No. 6 Seam | 7.0-13.9 | 4.0-4.8 | 11.0-13.6 | 41. |
| | | **Danville** | | | | |
| | | No. 7 Seam | 14.2-15.3 | 3.2-4.7 | 12.1-16.6 | 41. |
| | | **Southwestern** | | | | |
| | | No. 5 Seam | 8.3-10.7 | 3.1-4.5 | 11.3-12.4 | 39. |
| | | No. 6 Seam | 10.0-13.2 | 3.7-5.0 | 11.2-12.0 | 41. |
| | | **Southern Illinois** | | | | |
| | | No. 5 Seam | 4.2- 7.0 | 3.0-4.1 | 9.0-11.0 | 35. |
| | | No. 6 Seam | 4.3- 9.4 | 0.9-4.0 | 8.5-11.5 | 33. |
| | | DeKoven-Davis | 4.9- 6.0 | 3.5-5.2 | 8.5-13.6 | 35. |

A

| Percent Dry Basis | | | | | |
|---|---|---|---|---|---|
| Ash | Volatile Mater | Fixed Carbon | BTU, As Received | Coal Rank (ASTM) | Notes |
| 3.4- 7.5 | 33.0-42.0 | 51.1-58.7 | 13,150-14,340 | Hvab | |
| 3.4- 7.0 | 35.0-38.5 | 54.5-58.3 | 13,500-13,800 | Hvab | |
| 4.5-10.0 | 35.0-39.5 | 51.0-55.0 | 13,120-13,690 | Hvab | |
| 2.0- 8.6 | 33.0-39.0 | 53.0-58.0 | 13,120-14,110 | Hvab | |
| 1.2- 5.8 | 36.8-39.8 | 51.1-56.5 | 13,480-14,300 | Hvab | |
| 9.0-14.0 | 36.0-38.0 | 49.0-55.0 | 12,000-13,500 | Hvbb | |
| | | | | | Pocahontas seams are in District No. 7. |
| 3.5- 5.0 | 31.0-35.0 | 59.0-63.0 | 14,600-15,000 | Hvab | Excellent coking coal. |
| 2.0-10.0 | 33.0-38.0 | 54.0-62.0 | 13,350-14,460 | Hvab | Excellent coking coal. |
| 2.4- 6.0 | 21.3-26.0 | 65.0-70.1 | 14,050-15,300 | Mvb | Non-coking coal. |
| 5.0-11.0 | 21.0-35.0 | 54.0-68.0 | 13,000-15,000 | Hva-Lvb | Excellent coking coal. |
| 5.2- 7.5 | 32.6-34.5 | 55.8-60.6 | 13,650-14,400 | Hva-Mvb | Excellent coking coal. |
| 1.7- 4.6 | 34.1-38.6 | 55.4-61.4 | 13,750-14,750 | Hvab | Excellent coking coal. |
| 4.7- 5.8 | 31.5-34.0 | 58.5-61.2 | 14,600-14,800 | Hvab | Excellent coking coal. |
| 2.8-10.0 | 35.8-42.7 | 53.0-54.5 | 10,970-12,820 | Hvbb | The coal from this district is all steam coal. |
| 9.0-10.5 | 39.8-40.5 | 48.0-50.3 | 12,100-13,000 | Hvbb | |
| 0.1- 9.0 | 42.0-44.6 | 48.4-51.1 | 11,300-13,000 | Hvbb | |
| 7.0-13.4 | 38.3-40.2 | 41.2-52.3 | 10,660-13,100 | Hvbb | |
| 7.5-11.0 | 38.8-42.0 | 49.0-52.4 | 11,860-13,000 | Hvbb | |
| 5.9-10.4 | 40.7-45.4 | 46.0-53.2 | 11,000-11,340 | Hvcb | Keystone Coal Buyer's Manual - 1963 and Illinois Geological Survey Bulletin No. 62 and Supplement No. 62 (1948). |
| 9.2-12.8 | 40.0-45.2 | 44.0-46.3 | 10,700-11,250 | Hvcb | |
| 12.1-16.7 | 41.0-43.7 | 41.5-45.0 | 10,050-10,910 | Hvcb | |
| 9.6-12.1 | 40.0-45.0 | 40.3-46.2 | 10,620-11,470 | Hvcb | |
| 11.0-13.0 | 41.0-42.4 | 45.0-46.9 | 10,460-10,740 | Hvcb | |
| 10.6-13.8 | 39.0-45.0 | 42.0-50.0 | 9,750-10,680 | Hvcb | |
| 10.7-13.0 | 41.7-42.6 | 45.2-47.3 | 10,640-10,750 | Hvcb | |
| 11.0-13.6 | 41.0-45.0 | 45.0-47.0 | 10,700-11,800 | Hvcb | |
| 12.1-16.6 | 41.5-42.7 | 41.7-45.6 | 10,050-10,910 | Hvcb | |
| 11.3-12.4 | 39.4-40.7 | 46.5-49.8 | 11,150-11,670 | Hvbb | |
| 11.2-12.0 | 41.7-42.8 | 45.3-46.6 | 10,700-11,000 | Hvcb | |
| 9.0-11.0 | 35.5-37.0 | 48.5-52.0 | 11,890-12,730 | Hva-Hvbb | |
| 8.5-11.5 | 33.5-36.5 | 40.7-49.6 | 11,450-12,550 | Hva-Hvbb | |
| 8.5-13.6 | 35.7-37.0 | 45.8-50.2 | 12,000-12,600 | Hvab | |



B

Table 4. (continued)

| (1) Region No. | District of Origin | Name of Coal Beds | Moisture (Total) | Sulphur (Total) | Ash | Percent Dr Ve |
|---|---|---|---|---|---|---|
| IV | No. 11 Indiana | III Coal Seam | 11.0-13.7 | 0.9-7.6 | 8.9-13.8 | 40. |
| | | IV Coal Seam | 12.0-14.5 | 0.9-5.5 | 8.5-11.5 | 38. |
| | | V Coal Seam | 11.2-16.2 | 1.0-7.3 | 8.5-14.4 | 39. |
| | | VI Coal Seam | 11.2-13.5 | 1.4-6.0 | 8.4-11.8 | 39. |
| | | VII Coal Seam | 11.6-13.7 | 0.8-4.5 | 8.2-11.5 | 39. |
| V | No. 12 Iowa | Lower Cherokee Bed | 16.0-17.8 | 3.0-5.6 | 10.0-16.1 | 35. |
| III, VI | No. 13 Alabama (South Tennessee) | Mary Lee (Big Seam) (group includes 3 seams) | 1.2- 6.7 | 0.5-2.6 | 5.0-16.7 | 23. |
| | | Pratt Seam (group includes 4 seams) | 0.8- 4.2 | 0.5-3.0 | 3.0-14.2 | 20. |
| | | Black Creek Seam | 1.9- 5.8 | 0.5-2.5 | 1.3- 8.0 | 29. |
| | | Montevallo Seam | 1.0- 2.2 | 0.7-1.8 | 5.7-12.0 | 31. |
| | | Sewanee (Tenn.) (Upper Seam) | 1.4- 4.5 | 0.5-4.3 | 7.0-19.0 | 26. |
| VII, VIII | No. 14 Arkansas & Oklahoma Haskell-LeFore Sequoah Co. | Hartshorne Seam | 1.7- 3.7 | 0.7-3.1 | 5.2-14.2 | 16. |
| | | Paris Seam | 1.0- 2.5 | 2.5-2.8 | 4.7-11.7 | 16. |
| | | McAlester Seam | 1.6-6.3 | 0.7-3.0 | 4.3- 8.5 | 23. |
| V, VII | No. 15 Kansas, Missouri Oklahoma (Western) Texas | Mulberry Seam | 9.0-12.3 | 2.4-4.4 | 12.1-16.0 | 34. |
| | | Weir-Pittsburgh | 3.2- 5.6 | 2.9-5.8 | 10.4-13.2 | 32. |
| | | Bevier Seam | 14.4-16.1 | 3.6-6.2 | 12.1-16.3 | 37. |
| | | Tebo Seam | 9.1-15.1 | 3.1-6.7 | 8.5-14.4 | 39. |
| | | Henryetta Seam | 4.8- 6.6 | 1.0-2.0 | 5.3-12.6 | 30. |
| | | Secor Seam | 1.6- 3.0 | 3.0-4.7 | 9.2-11.8 | 34. |
| | | Texas Lignite | 20.7-41.5 | 0.6-2.0 | 9.0-17.7 | 42 |
| VIII | No. 16 Northern Colo. | Laramie Seam (Boulder-Denver Area) | 18.5-23.7 | 0.4-1.1 | 5.8- 9.0 | 34. |
| VIII | No. 17 Southern & Western Colorado New Mexico (Raton) Field | Allen Seam | 2.5- 6.2 | 0.5-0.6 | 5.2-10.8 | 32 |
| | | Cameo Seam | 7.0- 8.5 | 0.5-0.6 | 10.0-13.5 | 36 |
| | | Somerset Seam | 3.8- 5.7 | 0.4-0.6 | 5.0- 9.8 | 36 |
| | | Madge | 10.6-13.8 | 0.4-0.7 | 6.4- 7.5 | 40 |
| | | Raton Mesa | 1.3- 5.0 | 0.6-0.8 | 9.0-15.5 | 33 |
| VII | No. 18 New Mex. & Arizona | Mesaverde Seams | 3.0- 6.8 | 0.8-1.3 | 6.0-11.6 | 39 |

A

| Percent Dry Basis | | | | | |
|---|---|---|---|---|---|
| Ash | Volatile Matter | Fixed Carbon | BTU, As Received | Coal Rank (ASTM) | Notes |
| 8.9-13.8 | 40.6-44.8 | 45.0-47.5 | 10,500-12,530 | Hvcb | Indiana Geological Survey Bulletin No. 22-1961 and U.S.B.M. Coal Analysis Technical Paper 417. |
| 8.5-11.5 | 38.8-42.0 | 49.5-56.8 | 10,850-12,100 | Hvcb | |
| 8.5-14.4 | 39.6-41.7 | 42.6-49.3 | 11,000-12,300 | Hvcb | |
| 8.4-11.8 | 39.0-42.9 | 43.3-48.6 | 10,580-11,600 | Hvcb | |
| 8.2-11.5 | 39.0-43.2 | 43.8-52.2 | 10,460-11,400 | Hvcb | |
| 10.0-16.1 | 35.6-42.7 | 35.0-48.0 | 10,700-12,490 | Hvcb | U.S.B.M. Technical Paper 706, 1949. |
| 5.0-16.7 | 23.5-35.7 | 48.5-65.0 | 11,660-14,700 | Mvb | U.S.B.M. R.I. 6300 and 6461. Keystone Manual, 1964. |
| 3.0-14.2 | 20.5-35.8 | 49.5-67.5 | 12,600-14,600 | Mvb | |
| 1.3- 8.0 | 29.0-39.5 | 51.5-65.3 | 13,330-14,850 | Hvab | |
| 5.7-12.0 | 31.0-40.0 | 54.8-59.2 | 11,600-13,800 | Hvab | |
| 7.0-19.0 | 26.5-32.0 | 54.0-63.0 | 12,730-13,750 | Mvb | |
| 5.2-14.2 | 16.8-40.8 | 45.0-77.7 | 12,050-13,900 | Hvab | O.G.S. Bul. No. 4 & A.G.S. Bul. No. 1072 Arkansas - Lvb & Oklahoma - Hvab |
| 4.7-11.7 | 16.6-20.0 | 71.4-74.3 | 13,800-14,450 | Lvb | Low volatile, but high sulphur. |
| 4.3- 8.5 | 23.0-37.0 | 48.0-56.0 | 13,600-14,600 | Mvb | Some areas are Lvb. U.S.B.M. TP 416. |
| 12.1-16.0 | 34.6-35.4 | 48.6-53.2 | 11,200-11,300 | Hvcb | U.S.B.M. T.P. 455, 1930. |
| 10.4-13.2 | 32.5-36.3 | 50.2-54.8 | 11,190-13,000 | Hvcb | U. of Kansas, Bul. No. 5 |
| 12.1-16.3 | 37.5-39.7 | 46.2-49.4 | 10,845-11,500 | Hvcb | |
| 8.5-14.4 | 39.7-45.0 | 44.3-48.5 | 10,980-11,457 | Hvcb | |
| 5.3-12.6 | 30.8-35.6 | 50.0-54.0 | 11,600-13,500 | Hvbb | |
| 9.2-11.8 | 34.5-36.4 | 54.0-56.5 | 13,300-13,650 | Hvab | |
| 9.0-17.7 | 42.7-50.8 | 36.5-58.7 | 7,142- 8,450 | Lignite | U. of Texas, Bul. 4301, 1943. |
| 5.8- 9.0 | 34.4-42.9 | 51.3-57.1 | 8,840-10,550 | Subb | U.S.B.M., T.P. No. 574, 1937. |
| 5.2-10.8 | 32.7-35.0 | 54.0-55.7 | 12,900-13,300 | Hvab | U.S.B.M., T.P. No. 574, 1937. |
| 10.0-13.5 | 36.4-37.2 | 49.3-53.4 | 11,320-11,780 | Hvbb | |
| 5.0- 9.8 | 36.7-38.4 | 47.6-52.8 | 12,300-13,000 | Hvbb | |
| 6.4- 7.5 | 40.1-42.6 | 50.4-51.0 | 10,380-11,520 | Hvcb | |
| 9.0-15.5 | 33.8-38.0 | 48.6-55.8 | 12,800-13,510 | Hvab | Coking coal (U.S.G.S. Bul. No. 752). |
| 6.0-11.6 | 39.5-43.1 | 45.2-52.5 | 8,900-12,300 | Hvcb | U.S.G.S. Cir. 89, 1950. |



B

Table 4. (continued)

| (1) Region No. | District of Origin | Name of Coal Beds | Moisture (Total) | Sulphur (Total) | Ash |
|---|---|---|---|---|---|
| | | | | | Perce |
| VIII | No. 19 Wyoming | Rock Spring Seams | 7.5-11.0 | 0.7-0.9 | 1.5- 6.5 |
| | | Kemmerer No. 1 | 3.5- 7.0 | 0.4-0.9 | 4.0- 7.0 |
| | | Elkol Seam | 18.0-21.0 | 0.6-0.9 | 2.0- 5.0 |
| | | Big Horn Seam | 14.3-17.2 | 0.6-1.0 | 3.6- 8.3 |
| | | Gebo Seam | 12.7-17.6 | 0.4-1.1 | 3 5- 8.4 |
| VIII, IX | No. 20 Utah | Sunnyside Seams | 4.1- 4.8 | 0.7-0.8 | 6.3- 6.8 |
| | | Castelgate Seams | 4.9- 5.3 | 0.5-0.7 | 6.1- 6.9 |
| | | Hiawatha Seams | 4.6- 5.0 | 0.7-0.8 | 6.6- 7.0 |
| V | No. 21 North & South Dak. | Lignite Beds | 36.2 | 0.3* | 5.6* |
| IX | No. 22 Washington & Oregon | Roslyn Seam | 5.3- 6.0 | 0.4-0.5 | 15.0-15.8 |
| | | Wilkeson Seam | 5.0- 6.5 | 0.6-0.7 | 9.5-13.5 |
| | | Big Seam | 17.0-26.0 | 0.6-1.0 | 10.0-18.0 |
| IX | No. 23 Alaska | Matansuka Field | 8.5-21.0 | C.5-0.7 | 12.5-18.0 |
| | | Menana Field | 21.8-26.1 | 0.3-0.6 | 8.8-13.4 |

Notes:
(1) Regions are major regions of consumption; See Tables Nos. 2 and 3.
(2) Seams shown are major producing seams or potentially so. Some are both coking and steam coals. Regions of
(3) Range of analyses are generally widely variable due to (a) variation within the seams themselves, and (b) s
prepared coal bases. Where possible, run-of-mine analyses are used, which infer that they can be improve
(4) Sources of Analytical Data:
(a) U.S.B.M. Analysis of Tipple and Delivered Coal Analyses, various years.
(b) Keystone Coal Buyer's Manual - 1904.
(c) U.S.B.M. T.P. 455, 574, 345, 682.
(d) U.S.G.S. Bull. 474, 752, Cir. 81, 89.
(e) Geological Survey Reports, States of West Virginia, Illinois, Kentucky, Oklahoma, Iowa, Arkansas.
(f) University of Texas, Bul. 4301, 1943.

| Percent Dry Basis | | | | | |
|---|---|---|---|---|---|
| Ash | Volatile Matter | Fixed Carbon | BTU, As Received | Coal Rank (ASTM) | Notes |
| 1.5- 6.5 | 35.0-38.5 | 45.0-54.0 | 12,000-12,500 | Hvcb | U.S.G.S. Cir. 81, 1950. |
| 4.0- 7.0 | 40.5-42.5 | 45.5-48.5 | 12,400-12,800 | Hvcb | |
| 2.0- 5.0 | 41.0-43.0 | 50.0-53.0 | 10,000-10,400 | Hvbb | |
| 3.6- 8.3 | 37.8-43.0 | 52.8-56.2 | 10,390-11,490 | Subb | |
| 3.5- 8.4 | 37.5-42.3 | 53.2-54.3 | 10,640-11,600 | Subb | |
| 6.3- 6.8 | 37.9-38.4 | 51.7-55.6 | 13,000-13,800 | Hvbb | Coking Coal. |
| 6.1- 6.9 | 41.9-42.2 | 47.1-53.6 | 12,600-13,200 | Hvbb | U.S.B.M., T.P. No. 345, 1925 |
| 6.6- 7.0 | 41.2-41.8 | 47.6-54.1 | 12,850-13,500 | Hvbb | |
| 5.6* | 27.0* | 31.2* | 7,000* | Lignite | *As received basis, typical analysis. |
| 15.0-15.8 | 37.9-38.0 | 46.3-46.4 | 11,640-12,300 | Hvbb | U.S.G.S. Bul. No. 474, 1914 |
| 9.5-13.5 | 21.0-24.0 | 64.5-69.5 | 13,200-13,850 | Mvb | |
| 10.0-18.0 | 35.3-41.8 | 43.8-47.3 | 8,320- 9,070 | Subb | |
| 12.5-18.0 | 14.8-19.2 | 53.5-75.2 | 11,400-12,510 | Lvb | U.S.B.M. T.P. No. 682, Coals of Alaska |
| 8.8-13.4 | 45.5-50.2 | 33.8-48.2 | 8,430-11,400 | Lignite | 1946. |

coals. Regions of use are major consuming areas of coals from producing districts.
mselves, and (b) source of available data, in terms of run-of-mine, size analyses or
hey can be improved by coal washing methods.

Iowa, Arkansas.

B

(includes inherent and surface moisture), and the coal rank in accordance with ASTM designations. The districts of origin and regions of consumption are also given.

It will be noted that many of the coal beds or seams are listed as to counties or areas of a state. This is due either to the importance of the county as a coal producing area, or to the change in the characteristics of the coal from one part of the area to another. This is especially true of the Pittsburgh bed and the Nos. 5 and 6 Illinois beds.

The sources for the analyses are shown in the footnotes of Table No. 4. The larger single source is from published U.S. Bureau of Mines publications. This is particularly true of Appalachian coals. Midwest and western coal analyses were often obtained from state geological survey data, university bulletins, the Keystone manual and private sources.

It is practically impossible to tabulate an average analysis for a particular coal bed or seam. The wide range of analyses illustrate the great variance in the percentages of sulfur and other elements. Although attempts were made to show only raw coal (unwashed) analyses in this table, the sources of the data even from the Bureau of Mines, is often too uncertain to state whether all the coal samples were really a run-of-mine, a washed coal, a screened coal or a "channel" sample taken at the face of the mine. An arithmetical average of analyses would be meaningless because of the variable number of analyses, or that the analyses may be from a preponderance of samples from only one or two mines. In many cases the extremes of sulfur content may be unusual cases.

This table does show a usefulness, however, in giving the general characteristics of the coals and in helping in this study to narrow onto the higher sulfur coals for more detailed analyses.

## 3.5 Sulfur Content Variance and Types of Sulfur in the Major High Sulfur Coals

As a study of the various coal beds from the producing districts show, some coals are high quality coking coals and others are predominantly or exclusively steam coals. Ninety percent of all coal produced, for example, in District No. 7, is high quality (and high priced) low volatile coking coal. Coking coals also have to be low sulfur coals. The chief outlets for high sulfur coals are for steam raising purposes or space heating.

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## 3.6 Forms and Nature of Sulfur in Coal

As is well-known, sulfur occurs in coal in three forms. It is present in an organic combination as part of the coal substance, as pyrites or marcasite, and as sulfates.

Sulfates, mainly calcium and iron, rarely exceed a few hundredths percent, except in some highly weathered or oxidized samples. Organic sulfur, an inherent part of the coal substance itself, is in chemical combination with coal hydrocarbons and cannot physically be removed from coal, without changing the nature of the coal itself, i.e., to liquid or gaseous states.

It is often spoken of as "inherent" sulfur and from the viewpoint of coal preparation or coal washing, it cannot be removed no matter how fine the coal may be pulverized.

In fact, our only hope of removing any of the sulfur (other than by changing the nature of coal itself) is in removing pyrites or marcasites. These are two common forms of $FeS_2$, differing only in crystal structure and are usually difficult to distinguish one from the other. They are usually designated simply as pyrite.

Some pyrite is believed formed contemporaneously with coal and this is generally very finely disseminated. Iron sulfide in cleats and other cavities is believed to be of secondary origin. These usually consist of larger particles some of which may be quite large (more than a foot in diameter and called "sulfur balls"), others are in flat lenses or impregnated in the coal as crystals.

In coal preparation a theoretically "perfect" separation would be the removal of all iron sulfides or "pyrite", leaving only the organic sulfur left (sulfates are so small a percentage, they can practically be ignored). Even if this could be achieved in at present unknown processes, the sulfur (as organic sulfur) in some coals would still be quite high.

Table No. 5 shows some coals with organic or "inherent" sulfur contents as high as 2.70 percent. Many of the important seams in Illinois will run 2.00 percent organic sulfur or higher. Further, as previously stated, a variable percentage of pyrite is so finely disseminated that to all practical purposes, even with fine grinding, these sub-micron sizes can also be considered inherent. The term "inherent" sulfur in Table No. 6, however, pertains only to organic plus sulfate sulfur, as not enough data are available for determining the extent of finely disseminated pyrite, except in a few cases.

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CHICAGO 6, ILLINOIS

In order to narrow down the number of beds for further analyses, it was arbitrarily assumed that those beds whose total sulfur content were 2 percent or higher would be examined in further detail. Also eliminated were districts or areas (usually located by counties) where the sulfur content of otherwise high sulfur coals ran less than 2 percent.

This 2 percent limit is for total sulfur (that is, pyritic plus organic plus sulfate sulfur), and pertains to the raw coal as mined. Raw coals of less than 2 percent can be cleaned without too great a difficulty to 1.50 percent and frequently to less than 1.0 percent. Generally, the higher the total sulfur, the higher the percent of pyritic sulfur.

As can be seen from the analyses of Table No. 4, certain coal districts can be eliminated from this high sulfur category. This is true of District No. 7, southern West Virginia, previously mentioned, also, Eastern Kentucky, Virginia and much of Tennessee. All of the western coals, or Districts Nos. 17, 18, 19, 20, 21, 22 and 23 are low sulfur coals, generally less than 1 percent. The lignite coals of North and South Dakota and the subbituminous coals of the mountain states are, generally, quite low in sulfur content.

Table No. 5, therefore, concentrates on those coals where the sulfur analyses are habitually 2 percent or higher in the raw or run-of-mine. This table gives the range of total sulfurs for each coal bed and, where available, the percentages of the three types of sulfur found in coal, namely, pyritic, organic and sulfate sulfur.

This table lists 47 different coal beds that run 2 percent or higher in total sulfur or in which the seams in some areas will run this high or higher. The highest analysis listed (Indiana No. III) reaches 7.60 percent. It is not unusual to ship coal to power plants with sulfur as high as 6.50 percent. In the midwest, the East-North Central region, electric utility coal generally runs 3.00 to 4.50 percent. Some of the beds in Table No. 5 are listed more than once due to the use of local names, a change in their characteristics or the importance of the area. Examples are the Ohio No. 8 or Pittsburgh No. 8 bed, which geologically is the same as the Pittsburgh bed in Pennsylvania. The Kittanning and the Freeport beds in Ohio also are the same coal measures as found in Pennsylvania, but differ particularly in sulfur content.

Table No. 5-A gives an estimate of the minable coal reserves as of 1964, of the high sulfur coal beds listed in Table No. 5. The total estimated for 2 percent sulfur and higher coals is 75,123,475,000 tons with Illinois containing by far the largest tonnage (over 26 billion tons) of high sulfur coal.

Table 5. Distribution of Sulfur Forms in Major High Sulfur Coal Seams

| District of Origin | Name of Seam | Total Sulfur | | O |
|---|---|---|---|---|
| No. 1 Central Pennsylvania & Maryland | Lower Kittanning | 0.70 | 5.30 | 0.3 |
| | Middle Kittanning | 0.70 | 4.50 | 0.3 |
| | Upper Kittanning | 0.60 | 3.90 | 0.4 |
| | Lower Freeport | 0.50 | 4.30 | 0.3 |
| | Upper Freeport | 0.70 | 4.20 | 0.1 |
| No. 2 Western Pennsylvania | Pittsburgh Seam | 0.80 | 3.90 | 0.7 |
| | Brookeville Seam | 0.90 | 5.96 | 0.3 |
| | Clarion Seam | 0.90 | 6.30 | 0.3 |
| No. 3 and No. 6 Northern West Virginia and Panhandle District | Sewickley Seam | 1.60 | 4.20 | 0.7 |
| | Pittsburgh Seam | 0.90 | 4.82 | 0.5 |
| | Pittsburgh No. 8 | 2.70 | 5.00 | 0.5 |
| | Redstone | 1.60 | 4.35 | 0.8 |
| | Bakerstown | 0.60 | 3.93 | 0.2 |
| No. 4 Ohio | Pittsburgh No. 8 | 2.30 | 5.60 | 1.0 |
| | Lower Kittanning No. 5 | 2.30 | 5.80 | 0.4 |
| | Middle Kittanning No.6 | 1.50 | 4.80 | 0.4 |
| | Upper Freeport No. 7 | 2.20 | 5.70 | 0.4 |
| | Meigs Creek No. 9 | 2.30 | 6.40 | 1.4 |
| No. 7 West Virginia Pocahontas Fields | | | | All low S |
| No. 8 Central West Virginia, East Kentucky, Western Virginia and Northern Tennessee | Cedar Grove (W.Va.) | 0.50 | 2.80 | 0.3 |
| | No. 2 Gas (Pond Creek) | 0.62 | 2.10 | 0.4 |
| | Hazard (Hindman) | 1.60 | 2.80 | 0.7 |
| | Jellico (Tenn.) | 0.80 | 2.50 | 0.5 |
| | Blue Seam (Tenn.) | 0.70 | 2.20 | 0.2 |
| | Big Mary (Tenn.) | 2.00 | 4.40 | 0.6 |
| No. 9 West Kentucky | No. 6 Seam | 1.90 | 3.40 | 0.6 |
| | No. 9 Seam | 2.80 | 4.40 | 1.4 |
| | No. 11 Seam | 3.20 | 4.70 | 1.7 |
| | No. 12 Seam | 1.10 | 3.80 | 0.7 |
| | No. 14 Seam | 2.00 | 4.70 | 0.9 |

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| Percent Dry Basis | | | | | | | Sources of Data |
|---|---|---|---|---|---|---|---|
| Organic | | Sulfate | | Pyritic | | | |
| 0.36 | 0.55 | 0.01 | 0.07 | 0.33 | 4.60 | ) | U.S.B.M. T.P. 595 |
| 0.37 | 1.19 | 0.02 | 0.06 | 0.33 | 3.25 | ) | |
| 0.47 | 0.57 | 0.03 | 0.07 | 0.24 | .19 | ) | |
| 0.35 | 1.20 | 0.01 | 0.06 | 0.16 | .10 | ) | U.S.B.M. Bul. 496 |
| 0.11 | 1.14 | 0.01 | 0.06 | 0.52 | 3.00 | ) | |
| 0.70 | 1.75 | 0.01 | 0.02 | 0.10 | 2.15 | ) | U.S.B.M. Bul. 483 and |
| 0.35 | 1.54 | 0.02 | 0.08 | 0.55 | 3.15 | ) | Trans. AIME, June, 1963 |
| 0.35 | 1.70 | 0.02 | 0.05 | 0.55 | 4.65 | ) | U.S.B.M. T.P. 726, 1949 |
| 0.75 | 1.60 | na | | 0.85 | 2.45 | ) | |
| 0.55 | 1.67 | 0.02 | 0.08 | 0.25 | 3.25 | ) | |
| 0.50 | 1.97 | 0.01 | 0.09 | 1.60 | 3.20 | ) | W.Va. Geol. Sur. Vol. XIII (A), 1955. |
| 0.80 | 1.29 | 0.03 | 0.11 | 0.80 | 1.27 | ) | |
| 0.29 | 0.90 | 0.01 | 0.04 | 0.30 | 1.85 | ) | |
| 1.00 | 1.97 | 0.02 | 0.12 | 1.73 | 3.57 | ) | |
| 0.43 | 1.92 | 0.02 | 0.07 | 1.94 | 3.83 | ) | |
| 0.43 | 1.24 | 0.01 | 0.04 | 0.97 | 3.56 | ) | U.S.B.M. Bul. 499 |
| 0.43 | 1.03 | 0.02 | 0.06 | 1.28 | 4.72 | ) | |
| 1.42 | 2.60 | 0.08 | 0.29 | 1.78 | 3.50 | ) | Ohio State U. Exp. Sta., Bul. 165, 1957 |

All low Sulfur coals -- 1 percent or less.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0.38 | 0.62 | 0.01 | 0.06 | 0.11 | 1.12 | ) | |
| 0.45 | 0.56 | 0.02 | 0.05 | 0.17 | 1.50 | ) | U.S.B.M. T.P. 652 |
| 0.75 | 1.20 | 0.02 | 0.05 | 0.92 | 1.60 | ) | |
| 0.53 | 0.91 | 0.01 | 0.13 | 0.26 | 1.46 | ) | |
| 0.24 | ? | 0.02 | 0.04 | 0.44 | ? | ) | U.S.B.M. T.P. 671 |
| 0.68 | 1.93 | 0.02 | 0.06 | 1.08 | 2.49 | ) | |
| 0.66 | 1.02 | 0.03 | 0.10 | 1.20 | 2.28 | ) | |
| 1.45 | 1.84 | 0.00 | 0.09 | 1.35 | 2.63 | ) | U.S.B.M. T.P. 652 |
| 1.71 | 2.50 | 0.05 | 0.10 | 1.44 | 2.25 | ) | |
| 0.73 | 1.10 | 0.01 | 0.02 | 0.80 | 2.68 | ) | U. of Ill. Bul. 125, Engs. Exper. Sta. |
| 0.90 | 1.14 | 0.03 | 0.07 | 1.07 | 3.50 | ) | U.S.B.M. T.P. 652 |

Table 5. (Continued)

| District of Origin | Name of Seam | Total Sulfur | | Org |
|---|---|---|---|---|
| No. 10 Illinois | Colchester No.2 | 1.60 | 5.20 | 0.70 |
| | Rock Island No.1 | 4.80 | 6.50 | 1.50 |
| | Danville No.7 | 3.20 | 4.70 | 1.30 |
| | Illinois No.5 (Western Ill.) | 2.70 | 4.00 | 1.60 |
| | Illinois No. 5 (Springfield) | 3.30 | 4.90 | 0.90 |
| | Illinois No.5 (Southwestern) | 3.10 | 4.50 | 0.58 |
| | Illinois No. 6 (Northern Ill.) | 3.50 | 5.40 | 1.40 |
| | Illinois No.6 (Western Ill.) | 3.50 | 6.40 | 1.60 |
| | Illinois No.6 (South & Southwestern)* | 3.70 | 5.00 | 1.20 |
| | | *Note: There are low sulfur son counties that run | | |
| No. 11 Indiana | III Coal Seam | 0.90- | 7.60 | 0.62 |
| | IV Coal Seam | 0.90 | 5.50 | 0.77 |
| | V Coal Seam | 1.00 | 7.30 | 0.64 |
| | VI Coal Seam | 1.40 | 6.00 | 0.90 |
| | VII Coal Seam | 0.80 | 4.50 | 0.58 |
| No. 12 Iowa | Lower Cherokee Group | 3.00 | 5.60 | 1.22 |
| No. 13 Alabama and So. Tennessee | Mary Lee Group | 0.50 | 2.60 | 0.33 |
| | Pratt Seam Group | 0.50 | 3.00 | 0.42 |
| | Black Creek Seam | 0.50 | 2.50 | 0.32 |
| | Sewanee (Tenn.) | 0.50 | 4.30 | 0.43 |
| No. 14 Arkansas and Oklahoma | Hartshorne Seam | 0.70 | 3.10 | 0.53 |
| | Paris Seam | 2.50 | 2.80 | 0.82 |
| | McAlester Seam | 0.70 | 3.00 | 0.53 |
| No. 15 Kansas, Missouri and Oklahoma | Mulberry Seam | 2.40 | 4.40 | 0.88 |
| | Weir-Pittsburgh | 2.90 | 5.80 | 0.73 |
| | Bevier | 3.60 | 6.20 | 1.16 |
| | Tebo | 3.10 | 6.70 | 2.00 |
| | Secor | 3.00 | 4.70 | 1.32 |

NOTE: Range of sulfur in western coals -- Districts 16, 17, 18, 19, 20, 21, 22 and 23 are generally
this table.

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| Percent Dry Basis | | | | | | | |
|---|---|---|---|---|---|---|---|
| Organic | | Sulfate | | Pyritic | | | Sources of Data |
| 0.70 | 2.90 | 0.05 | 0.09 | 0.85 | 4.30 | ) | Ill.Geo.Sur.Bul. #62 |
| 1.50 | 2.00 | 0.01 | 0.02 | 2.80 | 4.50 | ) | & Supplement |
| 1.30 | 2.00 | 0.01 | 0.10 | 1.30 | 2.70 | ) | U. of Ill.Bul. 125, Eng. |
| | | | | | | ) | Exper. Sta. |
| 1.60 | 2.10 | 0.02 | 0.08 | 1.10 | 2.20 | ) | Ill.Geo.Sur.Bul. #64 |
| 0.90 | 2.40 | 0.02 | 0.05 | 1.80 | 2.70 | ) | |
| 0.58 | 1.70 | 0.01 | 0.06 | 1.40 | 3.90 | ) | |
| 1.40 | 1.90 | 0.01 | 0.02 | 1.60 | 3.50 | ) | Ill.Geo.Sur.Bul. #84 |
| 1.60 | 2.10 | 0.01 | 0.02 | 1.40 | 3.00 | ) | |
| 1.20 | 2.70 | 0.01 | 0.02 | 1.20 | 3.78 | ) | |

are low sulfur areas of No. 6 coal in Franklin-Jefferson and William-
ounties that run 1.0-1.6 percent total sulfur.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0.62 | 2.30 | 0.01 | 0.10 | 0.28 | 5.60 | ) | |
| 0.77 | 1.30 | 0.01 | 0.05 | 0.22 | 4/50 | ) | Private Sources |
| 0.64 | 1.70 | 0.02 | 0.04 | 0.34 | 5.60 | ) | |
| 0.90 | 1.66 | 0.03 | 0.08 | 0.47 | 4.26 | ) | U.S.B.M. - unpublished data |
| 0.58 | 1.20 | 0.02 | 0.05 | 0.20 | 3.25 | ) | |
| 1.22 | 2.01 | 0.05 | 0.14 | 1.78 | 3.50 | ) | U.S.B.M. RI 5362, 1957 |
| 0.33 | 0.66 | 0.00 | 0.04 | 0.16 | 1.90 | ) | |
| 0.42 | 1.14 | 0.01 | 0.10 | 0.08 | 2.18 | ) | Alabama U. Bul. No.6, |
| 0.32 | 0.75 | 0.01 | 0.09 | 0.18 | 1.61 | ) | Exper. Sta. |
| 0.43 | 1.16 | 0.01 | 0.05 | 0.07 | 3.00 | ) | U.S.B.M. T.P. 671 |
| 0.53 | 1.00 | 0.02 | 0.03 | 0.15 | 1.97 | ) | |
| 0.82 | 1.00 | 0.02 | 0.05 | 1.06 | 1.75 | ) | U.S.B.M. - unpublished data |
| 0.53 | 1.05 | 0.02 | 0.05 | 0.15 | 1.90 | ) | |
| 0.88 | 1.36 | 0.01 | 0.07 | 1.51 | 2.97 | ) | |
| 0.73 | 0.93 | 0.02 | 0.04 | 2.15 | 4.87 | ) | U.S.B.M. - unpublished data |
| 1.16 | 1.40 | 0.02 | 0.07 | 2.42 | 4.73 | ) | |
| 2.00 | 2.20 | 0.05 | 0.10 | 1.07 | 4.40 | ) | B.C.R., June, 1961 |
| 1.32 | 1.58 | 0.05 | 0.08 | 1.63 | 3.11 | | |

3 are generally under 1 percent total sulfur and are not considered in

Table No. 5-A Estimate of Minable Reserves of Major High Sulfur Coal Beds as of 1964 Based on Corps of Engineers Department of the Army Report for the Bureau of Mines on the Synthetic Liquid Fuels Potential of the United States 1950 and Present Production Information

| District of Origin | Name of Bed | Estimated Reserves Thousands of Tons |
|---|---|---|
| No. 1 Central Pennsylvania & Maryland | Lower Kittanning | 2,608,900 |
| | Middle Kittanning | 387,300 |
| | Upper Kittanning | 1,222,375 |
| | Lower Freeport | 1,703,825 |
| | Upper Freeport | 4,561,900 |
| | | 10,484,300 |
| No. 2 Western Pennsylvania | Pittsburgh Bed | 3,223,350 |
| | Brookeville Bed | 403,350 |
| | Clarion Bed | 126,225 |
| | | 3,752,925 |
| No. 3 and No. 6 Northern West Virginia and Panhandle District | Sewickley Bed | 710,275 |
| | Pittsburgh Bed | 5,275,700 |
| | Redstone | 626,100 |
| | Bakerstown | 252,000 |
| | | 6,864,075 |
| No. 4 Ohio | Pittsburgh No. 8 | 1,577,750 |
| | Lower Kittanning No. 5 | 396,025 |
| | Middle Kittanning No. 6 | 1,486,800 |
| | Upper Freeport No. 7 | 663,725 |
| | Meigs Creek No. 9 | 1,354,050 |
| | | 5,478,350 |
| No. 8 Central West Virginia, East Kentucky, Western Virginia and Northern Tennessee | Cedar Grove (W. Va.) | 1,337,050 |
| | No. 2 Gas (Pond Creek) | 1,296,050 |
| | Hazard (Hindman) | 779,125 |
| | Jellico (Tennessee) | 199,125 |
| | Blue Bed (Tennessee) | 23,125 |
| | Big Mary (Tennessee) | 107,050 |
| | | 3,741,525 |
| No. 9 West Kentucky | No. 6 Bed | 201,975 |
| | No. 9 Bed | 2,807,600 |
| | No. 11 Bed | 1,438,500 |
| | No. 12 Bed | 36,300 |
| | No. 14 Bed | 526,925 |
| | | 5,011,300 |

A

| Estimated Reserves Thousands of Tons | District of Origin | Name of Bed | Estimated Reserves Thousands of Tons |
|---|---|---|---|
| | No. 10 | | |
| 08,900 | Illinois | Colchester No. 2 | 586,625 |
| 87,300 | | Rock Island No. 1 | 88,400 |
| 22,375 | | Danville No. 7 | 262,125 |
| 03,825 | | Illinois No. 5 (Western Ill.) | 1,122,100 |
| 61,900 | | Illinois No. 5 (Springfield) | 3,319,400 |
| 84,300 | | Illinois No. 5 (Southwestern) | 2,800,300 |
| | | Illinois No. 6 (Northern Ill.) | 822,450 |
| 23,350 | | Illinois No. 6 (Western Ill.) | 9,618,500 |
| 03,350 | | Illinois No. 6 (South & South-western) | 7,994,800 |
| 26,225 | | | 26,614,700 |
| 52,925 | | | |
| | No. 11 | | |
| | Indiana | III Coal Bed | 1,411,225 |
| | | IV Coal Bed | 254,975 |
| 10,275 | | V Coal Bed | 4,285,400 |
| 75,700 | | VI Coal Bed | 903,975 |
| 26,100 | | VII Coal Bed | 109,975 |
| 52,000 | | | 6,965,550 |
| 64,075 | No. 12 | | |
| | Iowa | Lower Cherokee Group | 2,318,150 |
| | No. 13 | | |
| 77,750 | Alabama and So. Tennessee | Mary Lee Group | 562,400 |
| 96,025 | | Pratt Bed Group | 170,250 |
| 86,800 | | Black Creek Bed | 620,000 |
| 63,725 | | Sewanee (Tennessee) | 76,200 |
| 54,050 | | | 1,428,850 |
| 78,350 | | | |
| | No. 14 | | |
| 37,050 | Arkansas and Oklahoma | Hartshorne Bed | 889,300 |
| 96,050 | | Paris Bed | 40,900 |
| 79,125 | | McAlester Bed | 293,500 |
| 99,125 | | Henryetta | 368,150 |
| 23,125 | | | 1,591,850 |
| 07,050 | | | |
| 41,525 | No. 15 | | |
| | Kansas, Missouri and Oklahoma | Mulberry Bed | 9,850 |
| 01,975 | | Weir-Pittsburgh | 165,300 |
| 07,600 | | Bevier | 487,100 |
| 38,500 | | Tebo | 118,250 |
| 36,300 | | Secor | 91,400 |
| 26,925 | | | 871,900 |
| 11,300 | | | |
| | | | 75,123,475 |

PAUL WEIR COMPANY
20 NORTH WACKER DRIVE
CHICAGO 6. ILLINOIS

An illustration of this variable distribution of sulfur forms in coal is shown in Figure No. 1. The analyses are of the Pittsburgh bed, Greene County, Pennsylvania. These 37 face samples show the variation in organic sulfur, an "inherent" pyritic sulfur below 70 microns and a theoretical removable sulfur above this size. The analytical data for this bar chart is given in Figure No. 2. In this data only half of the pyritic sulfur could be considered removable by any known method other than by fine pulverization. In these U.S. Bureau of Mine tests the coal was crushed to minus 14 mesh and washed at 1.30 specific gravity.

It should be emphasized that not only are the forms of sulfur variable from one coal bed to another, but for the same bed from one area to another. Further, there is often a considerable variation in sulfur content in different layers of the bed at any given coal face.

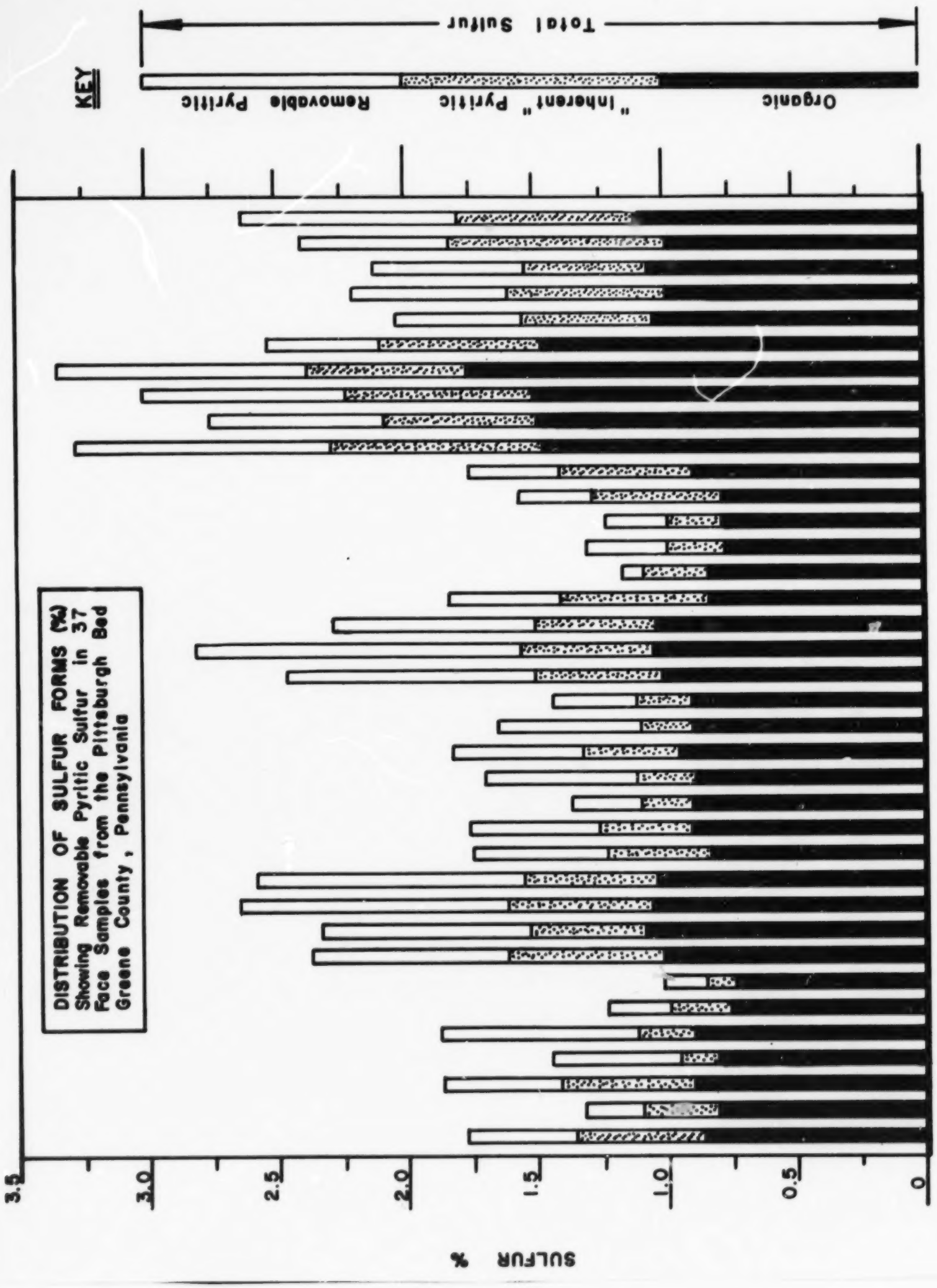
Figure No. 3 is a typical cross-section of the Pittsburgh bed in Greene County, showing bands of pyrite, other than finely disseminated particles. Figure No. 4 is a chart showing the variation of both ash and sulfur from top to bottom of coal faces from 30 mines in the Pittsburgh bed, Pittsburgh district taken by one of the larger coal companies.

Similar illustrations are shown for the commercially important Illinois No. 6 coal bed, in Franklin County. A typical cross-section is shown in Figure No. 5. Figure No. 6 shows the variation between organic and pyritic sulfur contents of the top bench of the coal bed taken in one Franklin County mine. Figure No. 7 shows analyses of the middle bench of coal at the same coal faces. Forty-two samples were taken because this represents the greater proportion of the seam. Figure No. 8 lists the analyses of this bench. Figure No. 9 shows the variation in sulfur of the bottom bench of coal at the same faces. Figure No. 10 shows the composite of the twelve face samples and the relative proportion of the top, middle and bottom benches.

In conducting this study of coal desulfurization, it should be mentioned that one outstanding difficulty arose in that in spite of intensive literature survey, personal contact with the numerous departments of government, individual coal companies, and individuals who have specialized in working on coal problems and the characteristics of coals in the United States, there is still a great paucity of information on not only the forms of sulfur in the many major coal beds of this country, but in grain or particle sizes of pyrite.

In regards to the latter, which is of vital importance to determining the extent of liberation possible by coal preparation methods, except for a few isolated studies, relatively little work has been done to show the results which can be achieved by fine grinding or crushing of coal. The data shown in this report on the effect of crushing to

Figure 1




Reference: Bureau of Mines, Bulletin 483, 1950

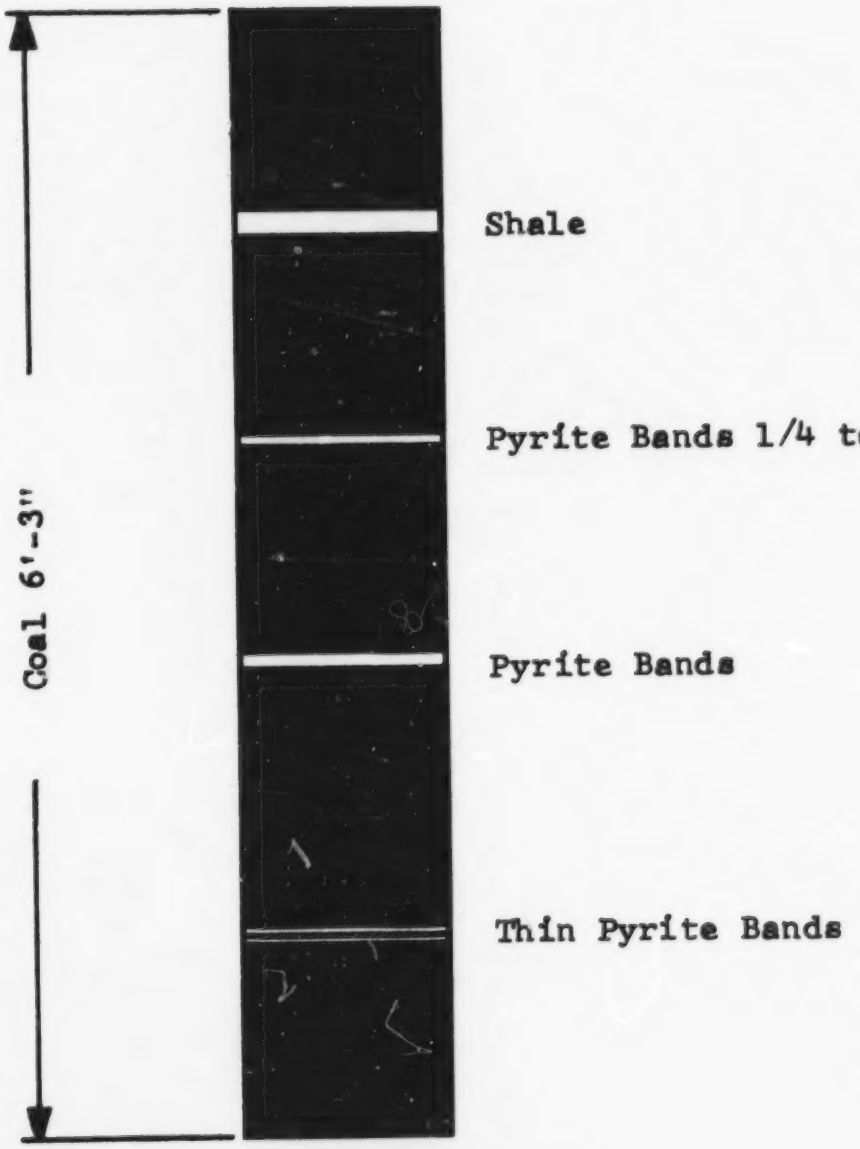
Distribution of Sulfur Forms (By %)
Showing Removable Pyritic Sulfur
In 37 Face Samples From the
Pittsburgh Bed - Greene County, Pennsylvania

| Sample | Organic | Total Pyritic | Removable Pyritic | Total Sulfur | Sample | Organic | Total Pyritic | Removable Pyritic | Total Sulfur |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.86 | 0.91 | 0.42 | 1.77 | 20 | 1.05 | 1.75 | 1.20 | 2.80 |
| 2 | 0.81 | 0.51 | 0.22 | 1.32 | 21 | 1.04 | 1.25 | 0.78 | 2.29 |
| 3 | 0.90 | 0.97 | 0.46 | 1.87 | 22 | 0.83 | 1.01 | 0.43 | 1.84 |
| 4 | 0.80 | 0.65 | 0.50 | 1.45 | 23 | 0.84 | 0.33 | 0.09 | 1.17 |
| 5 | 0.90 | 0.98 | 0.34 | 1.88 | 24 | 0.76 | 0.54 | 0.31 | 1.30 |
| 6 | 0.76 | 0.47 | 0.25 | 1.23 | 25 | 0.77 | 0.45 | 0.24 | 1.22 |
| 7 | 0.74 | 0.27 | 0.16 | 1.01 | 26 | 0.77 | 0.79 | 0.28 | 1.56 |
| 8 | 1.02 | 1.36 | 0.75 | 2.38 | 27 | 0.89 | 0.86 | 0.35 | 1.75 |
| 9 | 1.09 | 1.25 | 0.80 | 2.34 | 28 | 1.47 | 1.80 | 0.99 | 3.27 |
| 10 | 1.06 | 1.59 | 1.03 | 2.65 | 29 | 1.49 | 1.26 | 0.67 | 2.75 |
| 11 | 1.04 | 1.54 | 1.04 | 2.58 | 30 | 1.50 | 1.51 | 0.79 | 3.01 |
| 12 | 0.83 | 0.92 | 0.53 | 1.75 | 31 | 1.76 | 1.58 | 0.96 | 3.34 |
| 13 | 0.91 | 0.85 | 0.50 | 1.76 | 32 | 1.47 | 1.05 | 0.44 | 2.52 |
| 14 | 0.90 | 0.46 | 0.26 | 1.36 | 33 | 1.04 | 1.00 | 0.49 | 2.04 |
| 15 | 0.89 | 0.81 | 0.58 | 1.70 | 34 | 0.99 | 1.21 | 0.60 | 2.20 |
| 16 | 0.95 | 0.87 | 0.50 | 1.82 | 35 | 1.06 | 1.07 | 0.58 | 2.13 |
| 17 | 0.89 | 0.76 | 0.55 | 1.65 | 36 | 0.98 | 1.42 | 0.57 | 2.40 |
| 18 | 0.90 | 0.54 | 0.32 | 1.44 | 37 | 1.10 | 1.52 | 0.83 | 2.62 |
| 19 | 1.01 | 1.45 | 0.95 | 2.46 | | | | | |
| | | | | | Mean Values | 1.00 | 1.02 | 0.56 | 2.02 |

Figure 2

Figure 3

Distribution of Sulfur Forms
Pittsburgh Bed
Greene County, Pennsylvania



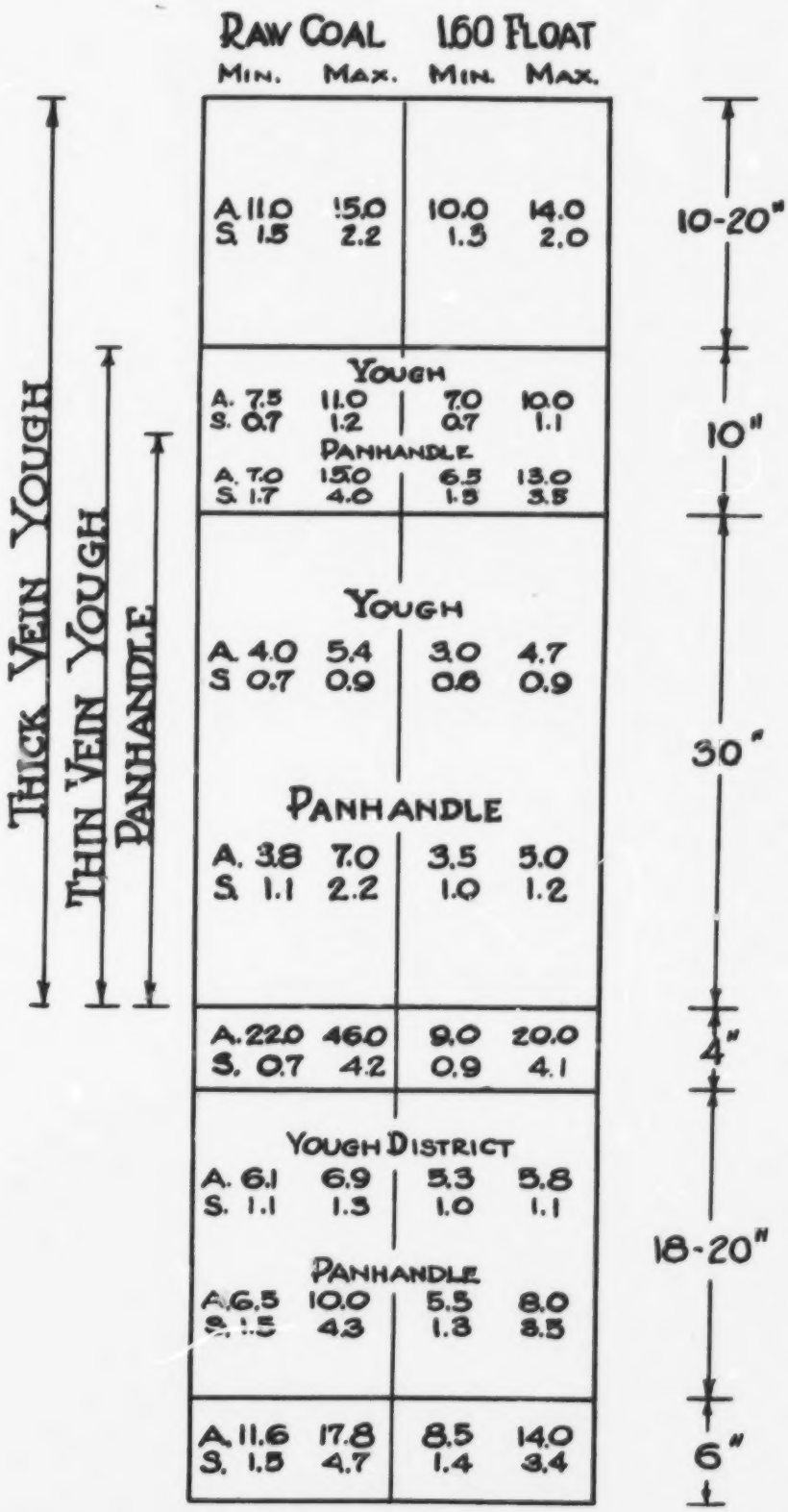

Typical Cross-Section of
Pittsburgh Bed in Greene County
Showing Occurrence of Pyritic Sulfur

Figure 4

PITTSBURGH SEAM - PITTSBURGH DISTRICT

# RANGE OF ASH AND SULPHUR IN SEAM

30 MINES - 742 SAMPLES OF EACH BENCH

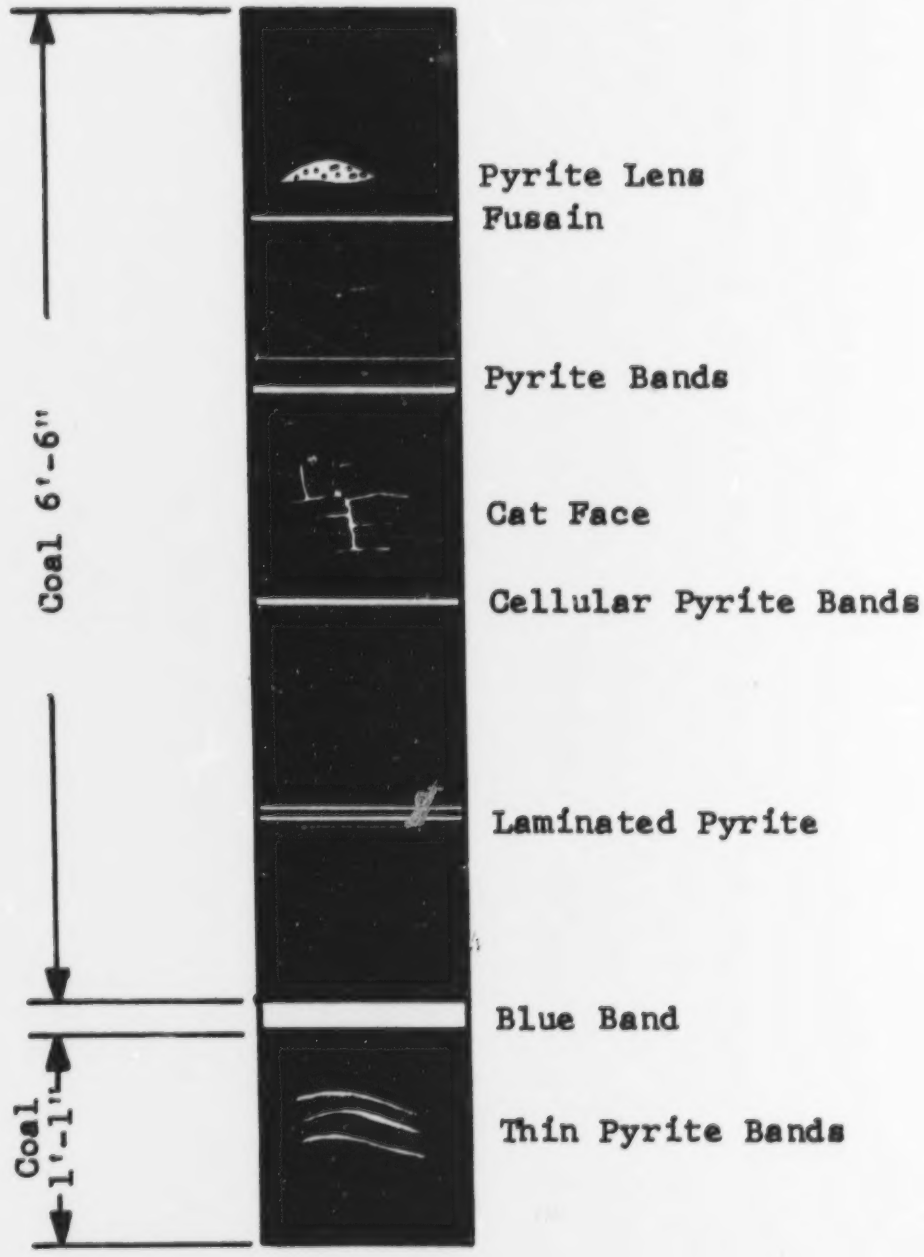



## TOTAL HEIGHT RANGE

| | |
|---|---|
| PANHANDLE | 61 to 66" |
| THIN VEIN YOUGH | 69 to 82"* |
| THICK VEIN YOUGH | 78‡ to 92" |

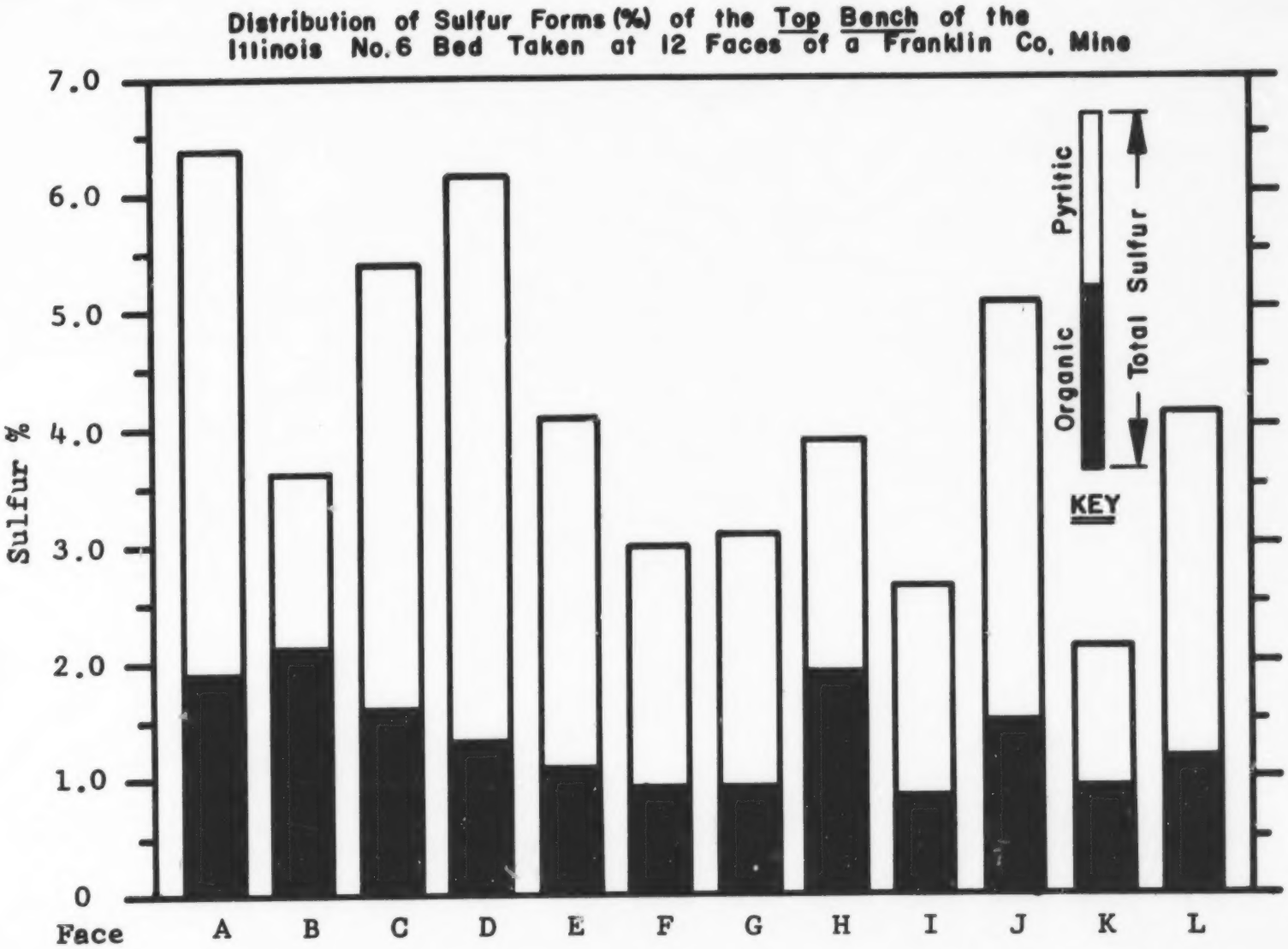
Figure 5

Distribution of Sulfur Forms
Illinois No. 6 Bed
Franklin County, Illinois



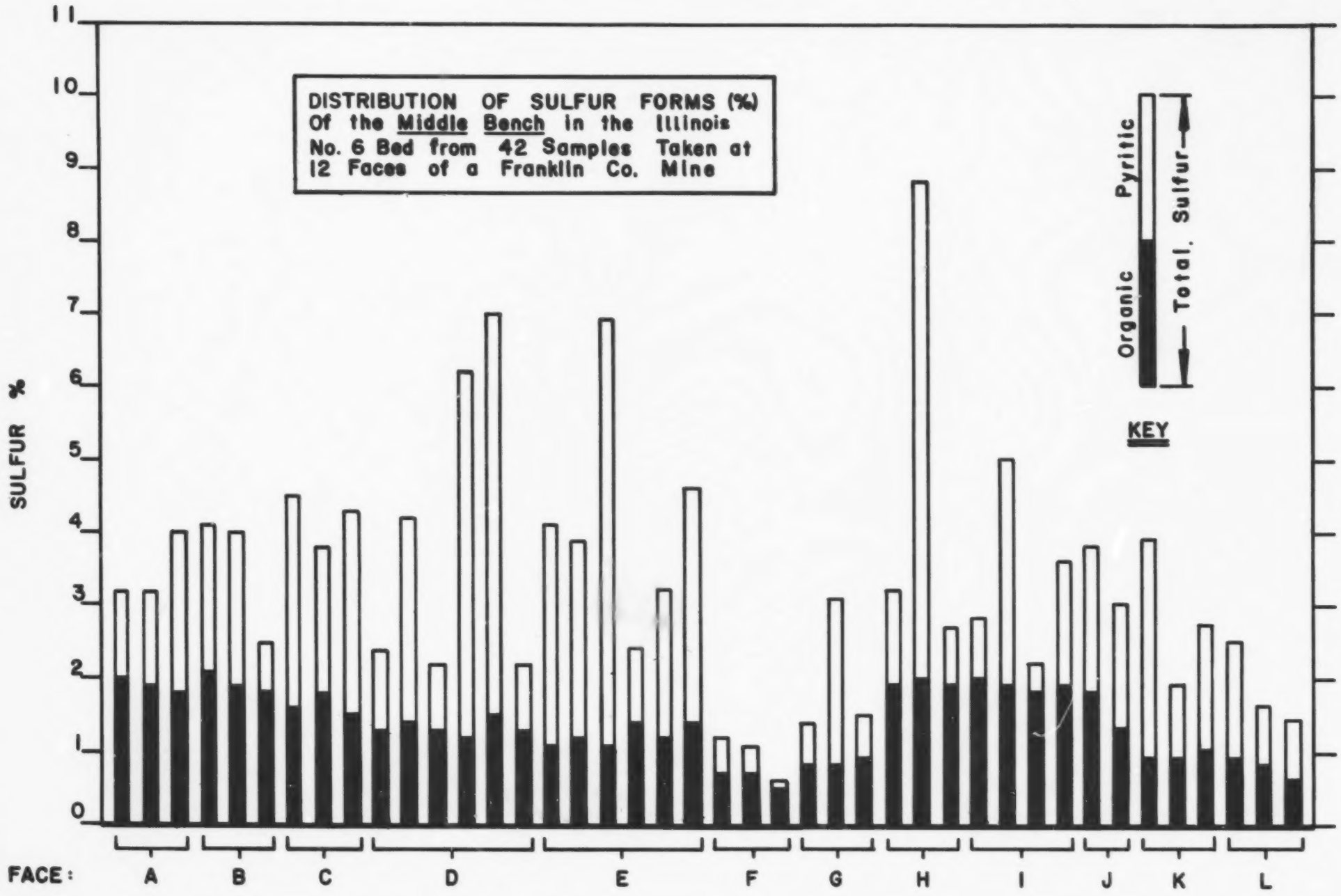

Typical Cross-Section of
Illinois No. 6 Bed in Franklin County
Showing Occurrence of Pyritic Sulfur

Figure 6




| Face Sample | Organic Sulfur | Pyritic Sulfur | Total Sulfur |
|---|---|---|---|
| A | 1.8 | 4.5 | 6.3 |
| B | 2.1 | 1.5 | 3.6 |
| C | 1.6 | 3.8 | 5.4 |
| D | 1.3 | 4.9 | 6.2 |
| E | 1.1 | 3.0 | 4.1 |
| F | 0.9 | 2.1 | 3.0 |
| G | 0.9 | 2.2 | 3.1 |
| H | 1.9 | 1.9 | 3.9 |
| I | 0.8 | 1.9 | 2.7 |
| J | 1.5 | 3.6 | 5.1 |
| K | 0.9 | 1.3 | 2.2 |
| L | 1.2 | 3.0 | 4.2 |
| Mean | 1.3 | 2.8 | 4.1 |

Reference: University of Illinois
Engineering Experiment Station
Bulletin 125 May 1921




Reference: University of Illinois
Engineering Experiment Station
Bulletin 125 May 1921

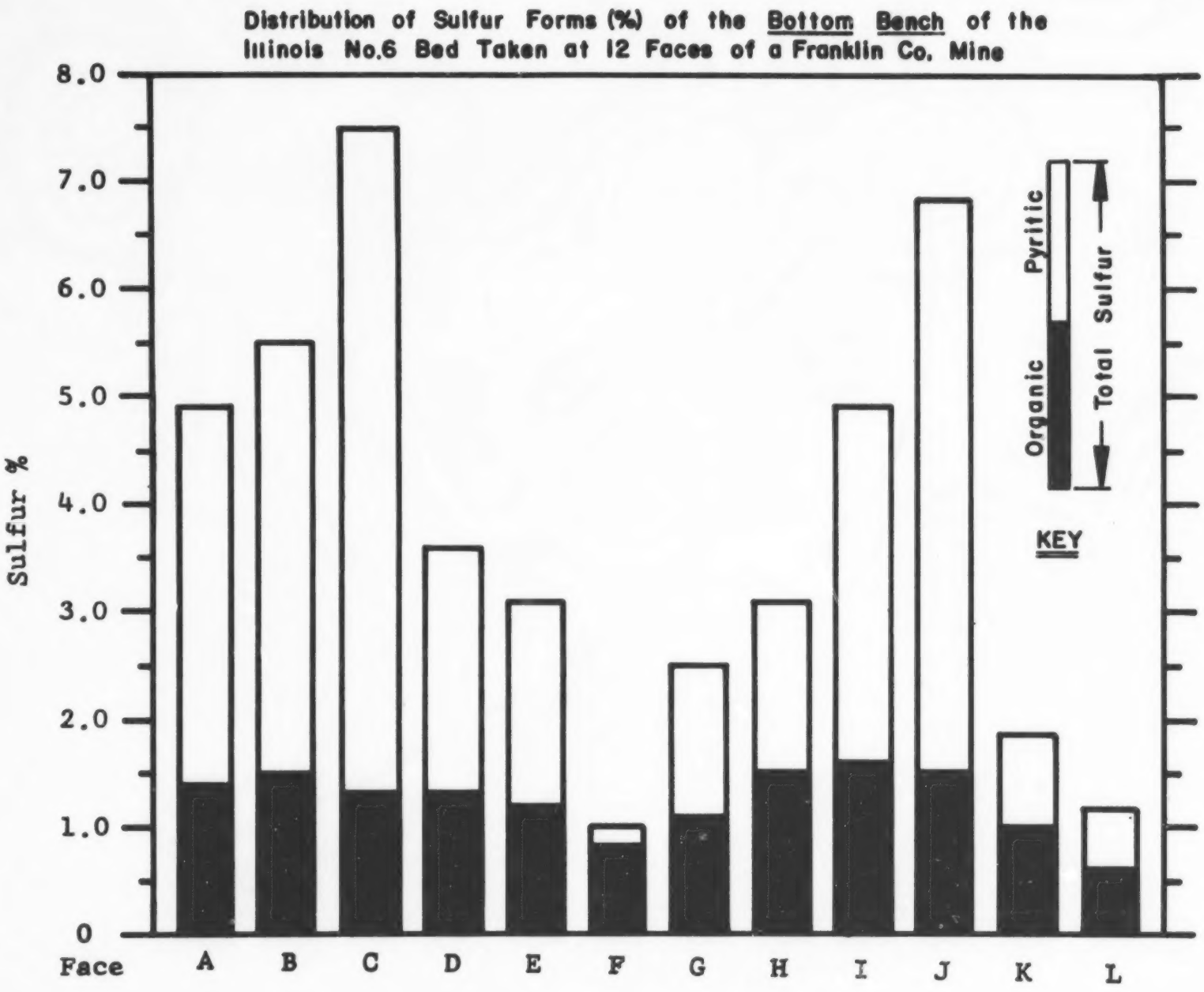
Figure 7

Figure 8

## Distribution of Sulfur Forms
## Illinois No. 6 Bed
## Franklin County, Illinois
## Middle Bench

| Face | Organic | Pyritic | Total | Face | Organic | Pyritic | Total |
|---|---|---|---|---|---|---|---|
| ( | 2.0 | 1.2 | 3.2 | ( | 0.7 | 0.5 | 1.2 |
| A( | 1.9 | 1.3 | 3.2 | F( | 0.7 | 0.2 | 0.9 |
| ( | 1.8 | 2.2 | 4.0 | ( | 0.5 | 0.1 | 0.6 |
| ( | 2.1 | 2.0 | 4.1 | ( | 0.8 | 0.6 | 1.4 |
| B( | 1.9 | 2.1 | 4.0 | G( | 0.8 | 2.3 | 3.1 |
| ( | 1.8 | 0.7 | 2.5 | ( | 0.9 | 0.6 | 1.5 |
| ( | 1.6 | 2.9 | 4.5 | ( | 1.9 | 1.3 | 3.2 |
| C( | 1.8 | 2.0 | 3.8 | H( | 2.0 | 6.8 | 8.8 |
| ( | 1.5 | 2.8 | 4.3 | ( | 1.9 | 0.8 | 2.7 |
| ( | 1.3 | 1.1 | 2.4 | ( | 2.0 | 0.8 | 2.8 |
| ( | 1.4 | 2.8 | 4.2 | I( | 1.9 | 3.1 | 5.0 |
| ( | 1.3 | 0.9 | 2.2 | ( | 1.8 | 0.4 | 2.2 |
| D( | 1.2 | 5.0 | 6.2 | ( | 1.9 | 1.7 | 3.6 |
| ( | 1.5 | 5.5 | 7.0 | | | | |
| ( | 1.3 | 0.9 | 2.2 | J( | 1.8 | 2.0 | 3.8 |
| | | | | ( | 1.3 | 1.7 | 3.0 |
| ( | 1.1 | 3.0 | 4.1 | | | | |
| ( | 1.2 | 2.7 | 3.9 | ( | 0.9 | 3.0 | 3.9 |
| ( | 1.1 | 5.8 | 6.9 | K( | 0.9 | 1.0 | 1.9 |
| E( | 1.4 | 1.0 | 2.4 | ( | 1.0 | 1.7 | 2.7 |
| ( | 1.2 | 2.0 | 3.2 | | | | |
| ( | 1.4 | 3.2 | 4.6 | ( | 0.9 | 1.6 | 2.5 |
| | | | | L( | 0.8 | 0.8 | 1.6 |
| | | | | ( | 0.6 | 0.8 | 1.4 |
| | | | | Mean Values | 1.4 | 2.0 | 3.4 |

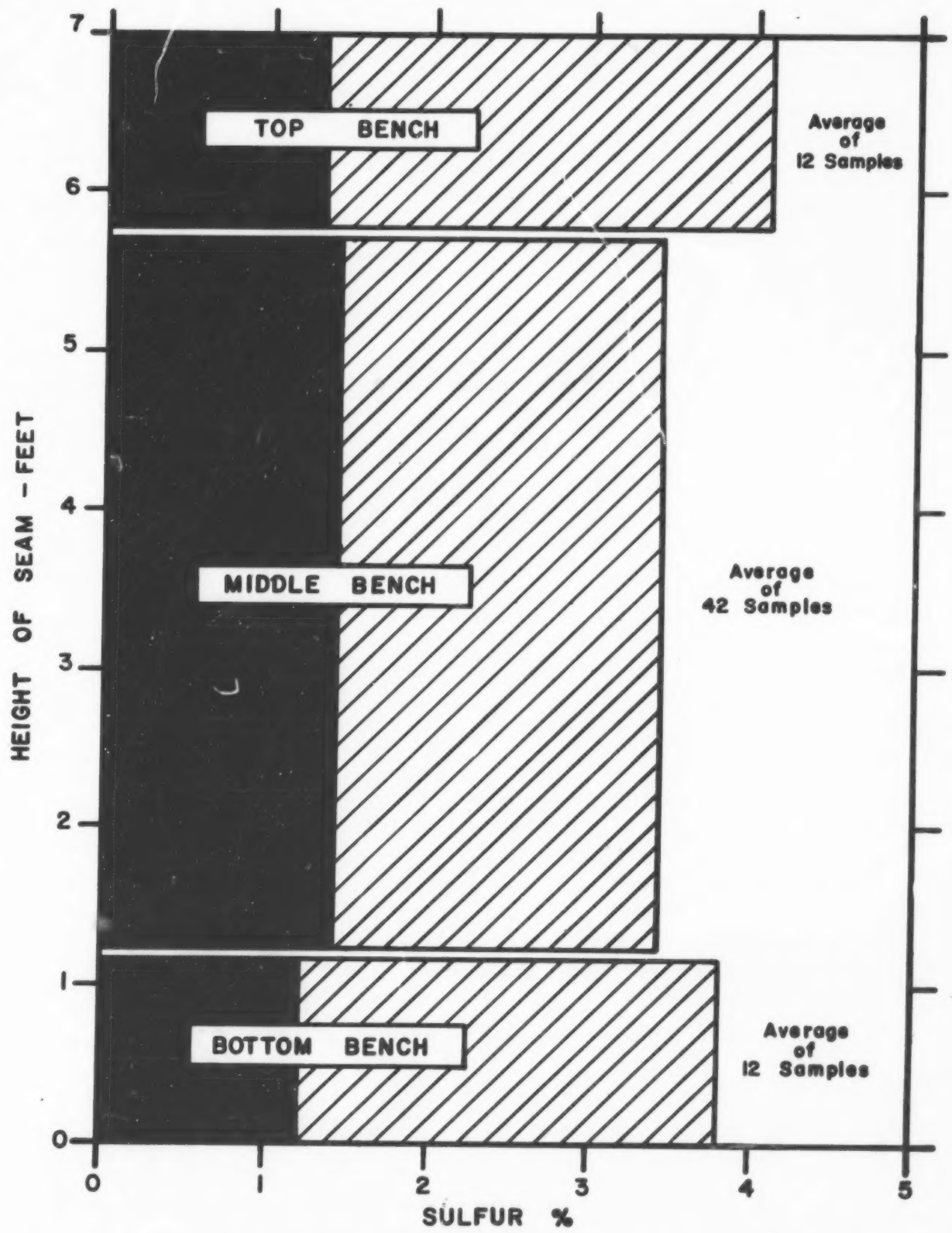
Figure 9




| Face Sample | Organic Sulfur | Pyritic Sulfur | Total Sulfur |
|---|---|---|---|
| A | 1.4 | 3.5 | 4.9 |
| B | 1.5 | 4.0 | 5.5 |
| C | 1.3 | 6.2 | 7.5 |
| D | 1.3 | 2.3 | 3.6 |
| E | 1.2 | 1.9 | 3.1 |
| F | 0.8 | 0.2 | 1.0 |
| G | 1.1 | 1.4 | 2.5 |
| H | 1.5 | 1.6 | 3.1 |
| I | 1.6 | 3.3 | 4.9 |
| J | 1.5 | 5.6 | 7.1 |
| K | 1.0 | 0.8 | 1.8 |
| L | 0.6 | 0.6 | 1.2 |
| Mean | 1.2 | 2.6 | 3.8 |

Reference: University of Illinois
Engineering Experiment Station
Bulletin 125 May 1921

Figure 10




Distribution of Sulfur Forms Showing Relation of Organic and Pyritic Sulfur Percents Vs. Bed Height in the Illinois No. 6 Bed Taken at 12 Faces of a Franklin Co. Mine

KEY: = Organic Sulfur
= Pyritic Sulfur

Reference: University of Illinois
Engineering Experiment Station
Bulletin 125 May 1921

liberate pyrite is the result of analyses on a very small percentage of the high sulfur coal beds in the United States. They may be typical, but until each bed and area is analyzed further, no one really knows what the limits of sulfur liberation can be for many of the major coal beds.

There is a fair amount of data available for Appalachian coals, many of which are reasonably low sulfur coals to begin with. This is understandable in that originally the main interest was in reducing certain coking coals to an acceptable sulfur level for metallurgical purposes. The idea of reducing sulfur of steam coals has only recently been brought to the attention of coal people.

As is shown in Table No. 6, where an attempt is made to tabulate the reduction of sulfur by crushing to various stages and separating at 1.30 and 1.60 specific gravities for the various high sulfur coals in the United States, there are many gaps of information that should be supplied for proper assessing of all American coals.

## 3.7 The Desulfurization of Coals by Means of Crushing and Specific Gravity Separation

We are aware of the various limitations surrounding the desulfurization or removal of sulfur from coals. In the first place there is no possible method of eliminating organic sulfur. This leaves the problem as to how much of the sulfur is in the form of iron sulfides (pyritic) and how much of the pyritic sulfur can be removed by known methods.

Crushing coals to various degrees liberates the pyrite particles from coal particles. Due to the difference in specific gravity of coal and pyrite, it can be determined fairly well how much pyrite can be removed from coal (and, therefore, to what degree the coal can be desulfurized).

We know that in the case of some coals, pulverizing to even 70 microns will only liberate part of the pyrite. Pulverizing coal to this fine a grind may be feasible, but it also complicates the separation and handling problems.

For physical handling of coal from mine to power plant or other end use, generally by railroad cars or barges, 1/4" is usually considered as the bottom size for the largest particles. For conveying by hydraulic pumping or belt conveyors, 14 mesh is usually considered to be top size. Further pulverization to perhaps 200 mesh (used for pulverized fuel burners) should be done at the power plant, unless some economic means can be found for transporting.

Table 6. Sulfur Reduction in Various High Sulfur Coal Beds and the Effect of Crushing - Based upon

ANALYSES ON DRY B

| Coal District | Coal Bed | Range of Sulfur as Mined % Total Sulfur | % Inherent Sulfur | % |
|---|---|---|---|---|
| **No. 1** | | | | |
| Pennsylvania & Maryland | Lower Kittanning | 0.70 - 5.30 | 0.37 - 0.62 | 1 |
| | | | | 1 |
| | Middle Kittanning | 0.70 - 4.50 | 0.37 - 1.25 | |
| | | | | 1 |
| | Upper Kittanning | 0.60 - 3.90 | 0.34 - 0.64 | 1 |
| | | | | 1 |
| | Lower Freeport | 0.50 - 4.30 | 0.34 - 1.21 | 1 |
| | | | | 1 |
| | Upper Freeport | 0.70 - 4.20 | 0.18 - 1.20 | 1 |
| **No. 2** | | | | |
| Western Pennsylvania | Pittsburgh | 0.80 - 3.90 | 0.70 - 1.77 | |
| | | | | 1 |
| | Brookeville | 0.90 - 5.96 | 0.37 - 1.62 | 1 |
| | Clarion | 0.90 - 6.30 | 0.53 - 1.75 | |
| | | | | 1 |

A

ased upon Specific Gravity Separation Conducted on Laboratory Samples

S ON DRY BASIS

| d Sulfur | Raw Coal % Ash | Raw Coal % Total Sulfur | Sp. Gr. | Crushed to - 1 1/2" Coal Yield | Crushed to - 1 1/2" % Sulfur | Crushed to - 3/8" Coal Yield | Crushed to - 3/8" % Sulfur | Crushed to - 1/4 Mesh Coal Yield | Crushed to - 1/4 Mesh % Sulfur |
|---|---|---|---|---|---|---|---|---|---|
| .62 | 12.5 | 1.10 | 1.30 | 26.6 | 0.67 | 32.9 | 0.70 | 42.3 | 0.69 |
| | | | 1.60 | 90.2 | 0.81 | 89.8 | 0.82 | 87.4 | 0.78 |
| | 18.3 | 3.80 | 1.30 | 18.0 | 0.66 | 24.0 | 0.68 | 34.6 | 0.70 |
| | | | 1.60 | 77.7 | 1.23 | 76.0 | 0.93 | 77.7 | 0.82 |
| .25 | 9.4 | 1.40 | 1.30 | 63.8 | 0.92 | 65.9 | 0.88 | ---- | ---- |
| | | | 1.60 | 93.2 | 1.17 | 91.9 | 1.03 | ---- | ---- |
| | 12.4 | 4.20 | 1.30 | 60.8 | 2.33 | 63.0 | 2.10 | 61.2 | 1.80 |
| | | | 1.60 | 86.6 | 2.39 | 88.4 | 2.48 | 86.6 | 2.04 |
| .64 | 12.4 | 2.20 | 1.30 | 26.7 | 0.99 | 34.6 | 1.00 | 18.8 | 0.90 |
| | | | 1.60 | 89.0 | 1.28 | 88.8 | 1.20 | 44.1 | 1.01 |
| | 14.0 | 3.90 | 1.30 | 38.4 | 0.95 | 53.1 | 0.76 | 55.1 | 0.75 |
| | | | 1.60 | 89.2 | 2.06 | 86.8 | 1.36 | 87.3 | 1.01 |
| .21 | 12.6 | 2.00 | 1.30 | 40.3 | 0.94 | 46.7 | 0.95 | 48.9 | 0.83 |
| | | | 1.60 | 90.1 | 1.53 | 89.3 | 1.42 | 88.4 | 1.25 |
| | 12.4 | 3.30 | 1.30 | 44.6 | 0.99 | 53.8 | 0.73 | 56.1 | 0.71 |
| | | | 1.60 | 87.1 | 1.40 | 86.6 | 0.91 | 85.4 | 0.78 |
| 1.20 | 11.6 | 1.60 | 1.30 | 54.0 | 0.90 | 63.8 | 0.78 | 62.9 | 0.78 |
| | | | 1.60 | 91.2 | 1.18 | 90.9 | 0.96 | 89.5 | 0.88 |
| | 9.2 | 3.20 | 1.30 | 52.8 | 1.40 | 64.7 | 1.19 | 68.3 | 1.00 |
| | | | 1.60 | 93.6 | 2.37 | 92.2 | 1.65 | 91.7 | 1.22 |
| 1.77 | 9.5 | 1.60 | 1.30 | 51.7 | 0.92 | 57.4 | 0.98 | 56.8 | 1.00 |
| | | | 1.60 | 93.8 | 1.35 | 93.4 | 1.32 | 92.8 | 1.28 |
| | 10.3 | 2.90 | 1.30 | 56.0 | 1.39 | 64.0 | 1.32 | 64.8 | 1.31 |
| | | | 1.60 | 94.9 | 2.03 | 93.5 | 1.77 | 92.9 | 1.58 |
| 1.62 | 11.6 | 1.70 | 1.30 | 70.1 | 0.65 | 70.9 | 0.58 | ---- | ---- |
| | | | 1.60 | 88.9 | 0.88 | 88.3 | 0.66 | ---- | ---- |
| | 8.9 | 4.40 | 1.30 | 58.5 | 1.77 | 65.2 | 1.55 | ---- | ---- |
| | | | 1.60 | 90.8 | 2.70 | 91.1 | 2.35 | 88.5 | 1.96 |
| 1.75 | 4.7 | 2.60 | 1.30 | 79.5 | 1.94 | 83.3 | 1.83 | 83.2 | 1.79 |
| | | | 1.60 | 97.8 | 2.24 | 97.0 | 2.08 | 96.3 | 1.98 |
| | 10.5 | 4.00 | 1.30 | 69.8 | 1.93 | 68.7 | 1.77 | 65.7 | 1.60 |
| | | | 1.60 | 89.0 | 2.23 | 89.3 | 2.07 | 88.6 | 1.86 |

B 37.

Table 6. (Continued)

| Coal District | Coal Bed | Range of Sulfur as Mined | |
|---|---|---|---|
| | | % Total Sulfur | % Inherent Sulfur |
| **No. 3 and No. 6** | | | |
| Northern West Virginia | Sewickley | 1.60 - 4.20 | 0.75 - 1.60 |
| | Pittsburgh | 0.90 - 4.82 | 0.57 - 1.75 |
| | Pittsburgh No. 8 | 2.70 - 5.00 | 0.50 - 2.06 |
| | Redstone | 1.60 - 4.35 | 0.83 - 1.40 |
| | Bakerstown | 0.60 - 3.93 | 0.30 - 0.94 |
| **No. 4** | | | |
| Ohio | Lower Kittanning No. 5 | 2.30 - 5.80 | 0.45 - 2.00 |
| | Middle Kittanning No. 6 | 1.50 - 4.80 | 0.44 - 1.28 |
| | Upper Freeport No. 7 | 2.20 - 5.70 | 0.45 - 1.09 |
| | Pittsburgh No. 8 | 2.30 - 5.60 | 1.02 - 2.09 |
| | Meigs Creek No. 9 | 2.30 - 6.40 | 1.50 - 2.89 |

| Sulfur | Raw Coal % Ash | Raw Coal % Total Sulfur | Sp. Gr. | Crushed to - 1 1/2" Coal Yield | Crushed to - 1 1/2" % Sulfur | Crushed to - 3/8" Coal Yield | Crushed to - 3/8" % Sulfur | Crushed to - 1 4 Mesh Coal Yield | Crushed to - 1 4 Mesh % Sulfur |
|---|---|---|---|---|---|---|---|---|---|
| .60 | 11.4 | 2.60 | 1.30 | 20.8 | 2.03 | 38.3 | 1.78 | 55.1 | 1.69 |
| | | | 1.60 | 97.1 | 2.44 | 93.8 | 2.27 | 95.4 | 2.08 |
| | 11.7 | 4.00 | 1.30 | 26.7 | 3.26 | 34.9 | 3.10 | ---- | ---- |
| | | | 1.60 | 93.8 | 3.90 | 92.8 | 3.72 | ---- | ---- |
| .75 | 9.0 | 2.90 | 1.30 | 60.5 | 1.70 | 66.8 | 1.56 | 66.7 | 1.45 |
| | | | 1.60 | 96.6 | 2.20 | 94.7 | 1.92 | 94.1 | 1.78 |
| | 9.2 | 4.30 | 1.30 | 48.6 | 2.29 | 64.9 | 2.16 | ---- | ---- |
| | | | 1.60 | 95.1 | 3.25 | 92.7 | 2.86 | ---- | ---- |
| .06 | 8.0 | 3.40 | 1.30 | 61.0 | 2.38 | 73.7 | 2.30 | ---- | ---- |
| | | | 1.60 | 95.2 | 3.11 | 93.9 | 2.79 | ---- | ---- |
| | 9.9 | 4.70 | 1.30 | 22.5 | 1.60 | 54.4 | 1.62 | 52.0 | 1.55 |
| | | | 1.60 | 92.9 | 3.32 | 89.9 | 2.57 | 88.6 | 2.33 |
| .40 | 7.4 | 2.00 | 1.30 | 49.9 | 1.36 | 54.4 | 1.37 | ---- | ---- |
| | | | 1.60 | 97.5 | 1.70 | 96.8 | 1.64 | ---- | ---- |
| | 11.9 | 3.30 | 1.30 | 21.9 | 2.14 | 42.5 | 2.04 | 37.8 | 1.99 |
| | | | 1.60 | 94.9 | 2.90 | 92.2 | 2.63 | 91.3 | 2.57 |
| .94 | 17.7 | 1.80 | 1.30 | 31.0 | 0.91 | 36.1 | 0.74 | ---- | ---- |
| | | | 1.60 | 79.5 | 1.39 | 78.1 | 0.98 | ---- | ---- |
| | 17.5 | 3.30 | 1.30 | 36.5 | 1.52 | 42.0 | 1.29 | ---- | ---- |
| | | | 1.60 | 79.8 | 2.39 | 77.4 | 1.65 | ---- | ---- |
| .00 | 13.9 | 2.40 | 1.30 | 11.0 | 0.85 | 15.7 | 0.83 | ---- | ---- |
| | | | 1.60 | 60.6 | 1.22 | 61.0 | 1.02 | ---- | ---- |
| | 11.7 | 5.00 | 1.30 | 59.1 | 2.20 | 59.9 | 2.09 | 63.4 | 2.01 |
| | | | 1.60 | 90.4 | 2.86 | 89.3 | 2.71 | 88.9 | 2.47 |
| .28 | 16.8 | 2.50 | 1.30 | 12.9 | 0.98 | 19.2 | 1.01 | 26.0 | 1.00 |
| | | | 1.60 | 89.5 | 1.82 | 87.3 | 1.64 | 84.8 | 1.45 |
| | 12.4 | 4.20 | 1.30 | 60.8 | 2.10 | 63.0 | 2.33 | 61.2 | 1.80 |
| | | | 1.60 | 86.6 | 2.39 | 88.4 | 2.48 | 86.6 | 2.04 |
| .09 | 16.2 | 2.50 | 1.30 | 43.1 | 0.80 | 47.3 | 0.68 | ---- | ---- |
| | | | 1.60 | 85.8 | 1.54 | 83.8 | 0.95 | ---- | ---- |
| | 22.2 | 3.90 | 1.30 | 27.9 | 1.08 | 31.5 | 0.86 | ---- | ---- |
| | | | 1.60 | 70.2 | 1.66 | 71.4 | 1.19 | ---- | ---- |
| .09 | 9.0 | 2.90 | 1.30 | 60.5 | 1.70 | 66.8 | 1.56 | 66.7 | 1.45 |
| | | | 1.60 | 96.6 | 2.20 | 94.7 | 1.92 | 94.1 | 1.78 |
| | 11.4 | 4.60 | 1.30 | 15.9 | 2.61 | 27.8 | 2.50 | ---- | ---- |
| | | | 1.60 | 92.9 | 4.44 | 92.2 | 4.15 | ---- | ---- |
| .89 | 24.8 | 3.90 | 1.30 | 1.0 | 2.50 | 11.3 | 2.33 | 14.9 | 2.27 |
| | | | 1.60 | 78.3 | 3.09 | 73.7 | 2.70 | 69.7 | 2.47 |

Table 6. (Continued)

| Coal District | Coal Bed | Range of Sulfur as Mined % Total Sulfur | % Inherent Sulfur |
|---|---|---|---|
| No. 4 (Cont'd) | Miegs Creek No. 9 | | |
| **No. 8** | | | |
| W. Virginia, East Kentucky Northern Tennessee | Cedar Grove | 0.50 - 2.80 | 0.39 - 0.68 |
| | No. 2 Gas | 0.62 - 2.10 | 0.47 - 0.61 |
| | Hazard (Kentucky) | 1.60 - 2.80 | 0.75 - 1.22 |
| | Jellico (Tennessee) | 0.80 - 2.50 | 0.54 - 1.04 |
| | Blue Gem (Tennessee) | 0.70 - 2.20 | 0.26 - 1.00 |
| | Big Mary (Tennessee) | 2.00 - 4.40 | 0.68 - 2.00 |
| **No. 9** | | | |
| West Kentucky | Seam No. 6 | 1.90 - 3.40 | 0.69 - 1.12 |
| | Seam No. 9 | 2.80 - 4.40 | 1.45 - 1.93 |
| | Seam No.11 | 3.20 - 4.70 | 1.76 - 2.13 |
| | Seam No.12 | 1.10 - 3.80 | 0.74 - 1.12 |
| | Seam No.14 | 2.00 - 4.70 | 0.93 - 1.21 |

Note: District No. 5 - Michigan not included as no coal mined in this district.
District No. 7 - So. West Virginia - all low sulfur coals not included.

| ulfur | Raw Coal % Ash | Raw Coal % Total Sulfur | Sp. Gr. | Crushed to - 1 1/2" Coal Yield | Crushed to - 1 1/2" % Sulfur | Crushed to - 3/8" Coal Yield | Crushed to - 3/8" % Sulfur | Crushed to - 1 4 Mesh Coal Yield | Crushed to - 1 4 Mesh % Sulfur |
|---|---|---|---|---|---|---|---|---|---|
| | 19.7 | 6.10 | 1.30 | 1.4 | 3.05 | 7.8 | 3.11 | 10.0 | 2.78 |
| | | | 1.60 | 81.8 | 4.72 | 79.0 | 4.28 | 69.4 | 3.67 |
| 68 | 9.9 | 1.30 | 1.30 | 56.8 | 0.93 | 59.8 | 0.95 | 59.9 | 0.94 |
| | | | 1.60 | 94.4 | 1.10 | 93.5 | 1.00 | 92.9 | 0.98 |
| | 8.0 | 1.90 | 1.30 | 66.6 | 1.15 | 70.8 | 1.18 | 71.9 | 1.10 |
| | | | 1.60 | 93.8 | 1.27 | 93.2 | 1.27 | 92.5 | 1.16 |
| 61 | 13.7 | 0.70 | 1.30 | 70.7 | 0.72 | 67.4 | 0.71 | ---- | ---- |
| | | | 1.60 | 86.3 | 0.74 | 85.9 | 0.74 | ---- | ---- |
| | 19.5 | 1.10 | 1.30 | 61.4 | 0.84 | 59.5 | 0.80 | 61.1 | 0.72 |
| | | | 1.60 | 79.2 | 0.87 | 79.5 | 0.85 | 80.2 | 0.77 |
| 22 | 18.0 | 1.60 | 1.30 | 27.2 | 0.83 | 33.0 | 0.72 | 44.0 | 0.63 |
| | | | 1.60 | 85.1 | 1.17 | 83.7 | 0.91 | 83.9 | 0.70 |
| | 11.8 | 2.60 | 1.30 | 52.4 | 1.21 | 58.3 | 1.21 | 61.5 | 1.31 |
| | | | 1.60 | 93.3 | 1.59 | 93.0 | 1.55 | 92.3 | 1.61 |
| 04 | 5.3 | 1.70 | 1.30 | 80.3 | 1.03 | 77.2 | 1.07 | 77.3 | 1.01 |
| | | | 1.60 | 96.6 | 1.29 | 96.0 | 1.29 | 95.5 | 1.20 |
| | 12.5 | 2.30 | 1.30 | 43.7 | 1.45 | 42.1 | 1.45 | 41.6 | 1.45 |
| | | | 1.60 | 89.7 | 1.98 | 89.0 | 1.90 | 87.7 | 1.83 |
| 00 | 10.2 | 1.90 | 1.30 | 55.8 | 1.27 | 63.6 | 1.25 | 59.8 | 1.19 |
| | | | 1.60 | 89.2 | 1.51 | 91.0 | 1.40 | 89.2 | 1.34 |
| | 6.6 | 2.20 | 1.30 | 75.2 | 0.84 | 74.5 | 0.90 | 82.2 | 1.01 |
| | | | 1.60 | 93.9 | 1.74 | 93.2 | 1.39 | 94.4 | 1.29 |
| 00 | 10.5 | 3.20 | 1.30 | 39.8 | 2.44 | 44.0 | 2.18 | 46.7 | 2.18 |
| | | | 1.60 | 95.5 | 2.58 | 93.5 | 2.30 | 92.4 | 2.22 |
| | 14.0 | 4.20 | 1.30 | 27.4 | 2.00 | 36.5 | 1.96 | 36.6 | 1.85 |
| | | | 1.60 | 88.5 | 2.55 | 85.3 | 2.27 | 85.5 | 2.02 |
| 12 | 7.12 | 3.00 | 1.50 | 85.2 | 1.70 | ---- | ---- | ---- | ---- |
| 93 | 10.67 | 3.34 | 1.50 | 84.0 | 2.54 | ---- | ---- | ---- | ---- |
| 13 | 8.59 | 3.90 | 1.50 | 86.3 | 2.89 | ---- | ---- | ---- | ---- |
| 12 | 18.65 | 3.80 | 1.50 | 78.8 | 3.20 | ---- | ---- | ---- | ---- |
| 21 | 8.20 | 3.10 | 1.50 | 85.7 | 2.58 | ---- | ---- | ---- | ---- |



B

Table 6. (Continued)

| Coal District | Coal Bed | Range of Sulfur as Mined % Total Sulfur | % Inherent Sulfur | % |
|---|---|---|---|---|
| No. 10 | | | | |
| Illinois | Rock Island No.1 | 4.80 - 6.50 | 1.51 - 2.02 | |
| | Colchester No.2 | 1.60 - 5.20 | 0.75 - 3.00 | |
| | Illinois No.5 (West) | 2.70 - 4.00 | 1.62 - 2.18 | |
| | Illinois No.5 (Springfield) | 3.30 - 5.49 | 0.92 - 2.45 | |
| | Illinois No.5 (So. West) | 3.10 - 4.50 | 0.60 - 1.76 | |
| | Illinois No.6 (Northern) | 3.50 - 5.40 | 1.41 - 1.92 | |
| | Illinois No.6 (Western) | 3.50 - 6.40 | 1.61 - 2.12 | |
| | Illinois No.6 (So. & So.W.) | 3.70 - 5.00 | 1.21 - 2.72 | |
| | Danville No. 7 | 3.20 - 4.70 | 1.31 - 2.10 | |
| No. 11 | | | | |
| Indiana | Coal Bed No. III | 0.90 - 7.60 | 0.63 - 2.40 | |

A

| ined Sulfur | Raw Coal % Ash | % Total Sulfur | Sp. Gr. | Crushed to - 1 1/2" Coal Yield | % Sulfur | Crushed to - 3/8" Coal Yield | % Sulfur | Crushed to - 1 4 Mesh Coal Yield | % Sulfur |
|---|---|---|---|---|---|---|---|---|---|
| 2.02 | 19.7 | 5.82 | 1.30 | 31.7 | 3.39 | ---- | ---- | ---- | ---- |
| | | | 1.70 | 86.5 | 4.68 | ---- | ---- | ---- | ---- |
| | 9.8 | 4.90 | 1.30 | 54.4 | 2.50 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 90.6 | 3.48 | ---- | ---- | ---- | ---- |
| 3.00 | 18.7 | 2.73 | 1.30 | 54.8 | 1.74 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 82.7 | 2.10 | ---- | ---- | ---- | ---- |
| | 17.6 | 1.99 | 1.30 | 68.8 | 1.02 | ---- | ---- | ---- | ---- |
| | | | 1.70 | 83.7 | 1.33 | ---- | ---- | ---- | ---- |
| 2.18 | 16.5 | 3.33 | 1.30 | 21.2 | 2.49 | ---- | ---- | ---- | ---- |
| | | | 1.70 | 92.9 | 3.02 | ---- | ---- | ---- | ---- |
| | 15.5 | 3.8[illegible] | 1.30 | 29.0 | 2.51 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 86.6 | 2.80 | ---- | ---- | ---- | ---- |
| 2.45 | 12.3 | 4.10 | 1.30 | 40.7 | 2.77 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 94.8 | 3.60 | ---- | ---- | ---- | ---- |
| | 17.6 | 5.49 | 1.30 | 30.8 | 3.32 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 86.9 | 4.28 | ---- | ---- | ---- | ---- |
| 1.76 | 11.6 | 2.82 | 1.30 | 52.6 | 1.48 | ---- | ---- | ---- | ---- |
| | | | 1.70 | 93.2 | 2.08 | ---- | ---- | ---- | ---- |
| | 10.2 | 4.18 | 1.30 | 33.3 | 1.43 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 93.1 | 1.94 | ---- | ---- | ---- | ---- |
| 1.92 | 26.4 | 4.37 | 1.30 | 43.7 | 2.60 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 73.3 | 3.07 | ---- | ---- | ---- | ---- |
| | 20.7 | 5.40 | 1.30 | 57.4 | 2.48 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 78.8 | 2.56 | ---- | ---- | ---- | ---- |
| 2.12 | 17.4 | 5.20 | 1.30 | 51.3 | 3.45 (4 x 0) | ---- | ---- | ---- | ---- |
| | | | 1.60 | 85.3 | 3.82 ( ) | ---- | ---- | ---- | ---- |
| | 15.5 | 5.12 | 1.30 | 40.8 | 3.58 (4 x 0) | ---- | ---- | ---- | ---- |
| | | | 1.60 | 88.6 | 4.18 ( ) | ---- | ---- | ---- | ---- |
| 2.72 | 15.2 | 4.30 | 1.30 | 35.3 | 2.87 (4 x 0) | ---- | ---- | ---- | ---- |
| | | | 1.60 | 89.7 | 3.25 ( ) | ---- | ---- | ---- | ---- |
| | 10.1 | 1.86 | 1.30 | 60.2 | 1.32 (2 x 0) | ---- | ---- | ---- | ---- |
| | | | 1.70 | 95.4 | 1.45 ( ) | ---- | ---- | ---- | ---- |
| 2.10 | 12.9 | 4.49 | 1.30 | 54.5 | 3.06 (5 x 0) | ---- | ---- | ---- | ---- |
| | | | 1.60 | 92.2 | 3.57 ( ) | ---- | ---- | ---- | ---- |
| | 10.2 | 3.51 | 1.30 | 63.0 | 2.94 ---- | ---- | ---- | ---- | ---- |
| | | | 1.60 | 95.5 | 3.20 ---- | ---- | ---- | ---- | ---- |
| 2.40 | 16.2 | 3.85 | 1.30 | ---- | ---- | 70.8 | 3.23 (1/4 x 0) | | ---- |
| | | | 1.60 | ---- | ---- | 87.2 | 3.35 (1/4 x 0) | | ---- |

40.

Table 6. (Continued)

| Coal District | Coal Bed | Range of Sulfur as Mined % Total Sulfur | % Inherent Sulfur |
|---|---|---|---|
| No. 11 (Cont'd) | Coal Bed No. III | | |
| | Coal Bed No. IV | 0.90 - 5.50 | 0.78 - 1.35 |
| | Coal Bed No. V | 1.00 - 7.30 | 0.66 - 1.74 |
| | Coal Bed No. VI | 1.40 - 6.00 | 0.93 - 1.76 |
| | Coal Bed No. VII | 0.80 - 4.50 | 0.60 - 1.25 |
| No. 12 | | | |
| Iowa | Lower Cherokee Group | 3.00 - 5.60 | 1.27 - 2.15 |
| No. 13 | | | |
| Alabama & So. Tennessee | Marylee Group | 0.50 - 2.60 | 0.33 - 0.70 |
| | Pratt Seam Group | 0.50 - 3.00 | 0.43 - 1.24 |
| | Black Creek | 0.50 - 2.50 | 0.33 - 0.84 |
| | Sewanee (Tennessee) | 0.50 - 4.30 | 0.44 - 1.21 |
| No. 14 | | | |
| Ark. & Oklahoma | Hartshorne | 0.70 - 3.10 | 0.55 - 1.02 |
| | Paris | 2.50 - 2.80 | 0.84 - 1.05 |
| | McAlester | 0.70 - 3.00 | 0.55 - 1.10 |
| | Henryetta | 1.00 - 2.00 | ---- |

NOTE: All other Western Districts are low sulfur coals, 1.0% or less.
Information on Appalachian coals obtained from U.S. Bureau of M
Information on other coals, from State, University and private

| d Sulfur | Raw Coal % Ash | Raw Coal % Total Sulfur | Sp. Gr. | Crushed to - 1 1/2" Coal Yield | Crushed to - 1 1/2" % Sulfur | Crushed to - 3/8" Coal Yield | Crushed to - 3/8" % Sulfur | Crushed to - 1 4 Mesh Coal Yield | Crushed to - 1 4 Mesh % Sulfur |
|---|---|---|---|---|---|---|---|---|---|
| | 9.1 | 4.10 | 1.50 | N.A. | 3.40 | ---- | ---- | ---- | ---- |
| - 1.35 | 8.3 | 1.90 | 1.50 | N.A. | 1.70 | ---- | ---- | ---- | ---- |
| | 9.2 | 1.90 | 1.50 | N.A. | 1.70 | ---- | ---- | ---- | ---- |
| - 1.74 | 17.6 | 5.34 | 1.30 | 33.3 | 3.03 (6 x 0) | | ---- | ---- | ---- |
| | | | 1.60 | 86.6 | 3.72 ( ) | | ---- | ---- | ---- |
| | 10.0 | 3.66 | 1.50 | N.A. | 3.09 | ---- | ---- | ---- | ---- |
| - 1.76 | 9.3 | 2.61 | 1.50 | N.A. | 2.21 | ---- | ---- | ---- | ---- |
| - 1.25 | 8.8 | 1.00 | 1.50 | N.A. | 0.90 | ---- | ---- | ---- | ---- |
| | 8.0 | 2.90 | 1.50 | N.A. | 2.40 | ---- | ---- | ---- | ---- |
| - 2.15 | 17.9 | 5.56 | 1.30 | 59.7 | 3.89 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 82.8 | 4.40 | ---- | ---- | ---- | ---- |
| | 12.2 | 5.41 | 1.30 | 71.9 | 4.21 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 93.3 | 3.57 | ---- | ---- | ---- | ---- |
| - 0.70 | 29.9 | 0.72 | 1.30 | 31.5 | 0.69 | ---- | ---- | ---- | ---- |
| | | | 1.70 | 72.5 | 0.69 | ---- | ---- | ---- | ---- |
| | 17.4 | 0.97 | 1.30 | 59.3 | 0.80 (1 x 0) | | ---- | ---- | ---- |
| | | | 1.60 | 88.7 | 0.87 ( ) | | ---- | ---- | ---- |
| - 1.24 | 11.6 | 2.62 | 1.30 | 68.5 | 1.63 (3 x 0) | | ---- | ---- | ---- |
| | | | 1.70 | 90.4 | 2.03 ( ) | | ---- | ---- | ---- |
| | 14.9 | 2.58 | 1.30 | ---- | ---- | 59.1 | 1.14 (3/16 x 0) | | ---- |
| | | | 1.70 | ---- | ---- | 84.7 | 1.68 ( ) | | ---- |
| - 0.84 | 10.8 | 2.05 | 1.30 | 69.1 | 1.29 (3 x 0) | | ---- | ---- | ---- |
| | | | 1.70 | 90.6 | 1.74 ( ) | | ---- | ---- | ---- |
| - 1.21 | 15.9 | 2.61 | 1.30 | 10.8 | 1.06 (4 x 0) | | ---- | ---- | ---- |
| | | | 1.70 | 92.2 | 2.07 ( ) | | ---- | ---- | ---- |
| - 1.02 | 9.60 | 2.70 | 1.35 | 32.5 | 0.90 | ---- | ---- | ---- | ---- |
| | | | 1.60 | 93.0 | 2.00 | ---- | ---- | ---- | ---- |
| | 14.7 | 3.10 | 1.30 | ---- | ---- | 64.7 | 2.37 | ---- | ---- |
| | | | 1.60 | ---- | ---- | 82.9 | 6.76 | ---- | ---- |
| - 1.05 | Not Available | | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| - 1.10 | Not Available | | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| --- | 7.0 | 1.70 | 1.30 | 79.9 | 0.98 | 82.4 | 0.96 | 85.8 | 0.97 |
| | | | 1.58 | 93.8 | 1.14 | 93.7 | 1.15 | 93.6 | 1.10 |

% or less.
ureau of Mines.
d private sources.

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20 NORTH WACKER DRIVE
CHICAGO 6, ILLINOIS

The impurities in coal, including pyrite, are generally removed by developing equipment to take advantage of the differences in specific gravity of these impurities and the coal substances. Although pure coal may have a specific gravity as low as 1.27 and pyrite 4.9, coal is a heterogenous material containing higher density carbonaceous materials and many coal-pyrite particles will be intertwined giving a variable specific gravity for coal-pyrite mixtures, or coal-rock mixtures.

To determine the relative relationship between coal and its various grades of impurities, a series of liquids are made up in the laboratory at certain densities, usually in the ranges of as low as 1.30 to as high as 2.0, and the impure coal immersed in these liquids. Thus a specific gravity-yield ash and/or sulfur content relationship can be determined. Material of a specific gravity higher than 1.90 or 2.00 contains little combustible matter and is usually considered "rock" or reject.

These are called "float and sink" analyses, and the results of this information can be plotted as curves called "washability curves".

With this tool and by crushing coal to various sizes, a good relationship can be determined between coal quality -- in terms of percent ash or percent sulfur content and the yield of product by weight percent from the original coal as mined.

Coal preparation plants or washeries operate on the basis of this relationship. Plant "efficiencies" are usually based upon comparing actual results with laboratory float and sink tests (the theoretical possible yield and grade).

It should be mentioned, however, that as the purer coal substance is achieved, the organic sulfur will concentrate and where the organic sulfur content is abnormally high, a point may be reached at the low gravities of separation where the sulfur percentage is higher than what it would have been at the higher densities of separation.

Table No. 6 is a collection of data obtained from laboratory float and sink tests of various major coal beds. Where possible, data are presented on coals crushed to minus 1-1/2 inches, minus 3/8 inches and to minus 14 mesh. As the table shows, however, there are many blanks for coals other than Appalachian showing the effect of crushing to these sizes.

Table No. 6 lists the separation at generally two specific gravities, one at 1.30 and the other at 1.60. The latter is the average separating density for most steam coals. 1.30 approaches the lower limit of possible separation. In actual practice 1.35 would be considered the minimum for most coals and even at that level generally uneconomical.

PAUL WEIR COMPANY
20 NORTH WACKER DRIVE
CHICAGO 6, ILLINOIS

Coking coals are washed at densities as low as 1.35, but generally in the range of 1.35 to 1.55. Steam coals, when washed are usually separated at densities of 1.60 to 1.80. Under some difficult situations they may be washed at 1.50.

Two sets of tests are shown for each coal; one where the raw or head sample is relatively low in sulfur and the other where the raw or head sample is relatively high. These cannot, obviously, follow the extreme lower and upper limits shown in previous data on sulfur limits, but show only the results of particular tests.

This compilation of data shows that the sulfur of some coals can be reasonably reduced by washing or separating at these separating densities, while others show very little effect in sulfur reduction. Some show a marked improvement by crushing while others, at least to 14 mesh, show only a small percentage of reduction. Also, separating at the low density of 1.30 has to be ruled out due to the great loss of coal yield.

Actually each coal bed has to be examined separately to determine the ultimate sulfur level to which it can be cleaned. Central Pennsylvania coals such as the Freeport, Kittanning and Pittsburgh beds respond fairly well in liberating pyrite (sulfur) by crushing and washing at reasonable densities. Coals in Western Pennsylvania, Northern West Virginia and most of those in the midwest states are much more difficult to lower sulfur content.

Table No. 7 gives examples of Pennsylvania coal beds, by counties, where pyrite removal is relatively easy by crushing and washing at normal separating densities. Upper Kittanning in Cambria County, for example, shows a reduction from 3.76 percent sulfur to as low as 0.90 percent by crushing the coal to 14 mesh and separating at the high specific gravity of 1.60. It shows a Middle Kittanning seam with a head sulfur of 5.64 percent being reduced to 1.57 percent by crushing to minus 3/8 inches.

Figure No. 11 shows an interesting relationship by separating Pittsburgh bed 3/8" x 14 mesh coal at 1.35 and 1.60 specific gravities for raw coal of varying sulfur levels. The lower sulfur coals indicate only a 0.20 percent difference in sulfur between the two densities while this difference spreads to 0.30 percent in the higher sulfur content coal.

A similar type of curve is shown in Figure No. 12 for Illinois No. 6 bed, for coal of various head sulfurs, separated at 1.35 and 1.50 specific gravities, after crushing the coal to minus 1-1/2 inches. A 0.70 percent sulfur difference is noted at the 5.0 percent sulfur raw coal level, while there is only a 0.30 percent difference at the 3.0 percent level.

Table No. 7

Examples of Pennsylvania Coal Beds, by Counties, Where Pyrite Removal is Relatively Easy thr
at Normal Operating Gravities.

| Coal Bed | County | Head Ash % | Head Sulfur % | Sp. Gr. | 1 1/2" x 0 Yield | 1 1/2" x 0 Ash | 1 1/2" x 0 Sulfur | 3/8" x Yield |
|---|---|---|---|---|---|---|---|---|
| Upper Kittanning | Cambria | 12.3 | 3.76 | 1.60 | 87.5 | 8.9 | 1.86 | 87.2 |
| Lower Kittanning | " | 18.0 | 3.38 | 1.60 | 77.7 | 8.6 | 1.31 | 76.0 |
| Middle Kittanning | Butler | 12.8 | 5.64 | 1.48 | 83.9 | 6.8 | 3.10 | 83.1 |
| Upper Freeport | Indiana | 14.3 | 2.62 | 1.50 | 81.6 | 7.2 | 1.53 | 80.2 |
| Lower Freeport | Armstrong | 8.5 | 2.64 | 1.46 | 91.0 | 5.0 | 1.82 | 90.2 |
| Lower Freeport | Cambria | 17.3 | 3.29 | 1.50 | 75.8 | 6.7 | 1.85 | 74.9 |
| Brookville | Clearfield | 26.0 | 5.00 | 1.55 | 60.8 | 10.3 | 2.62 | 59.7 |
| Clarion | Jefferson | 11.4 | 4.57 | 1.45 | 85.8 | 6.0 | 2.15 | 85.3 |
| Pittsburgh | Greene | 10.0 | 2.27 | 1.47 | 92.3 | 7.1 | 1.71 | 91.2 |

NOTE: Above data is obtained from: "The Preparation Characteristics of Bituminous Coal Re
Emphasis on Sulfur Reduction". No. SR-35, Oct. 1962, College of Mineral Industries.

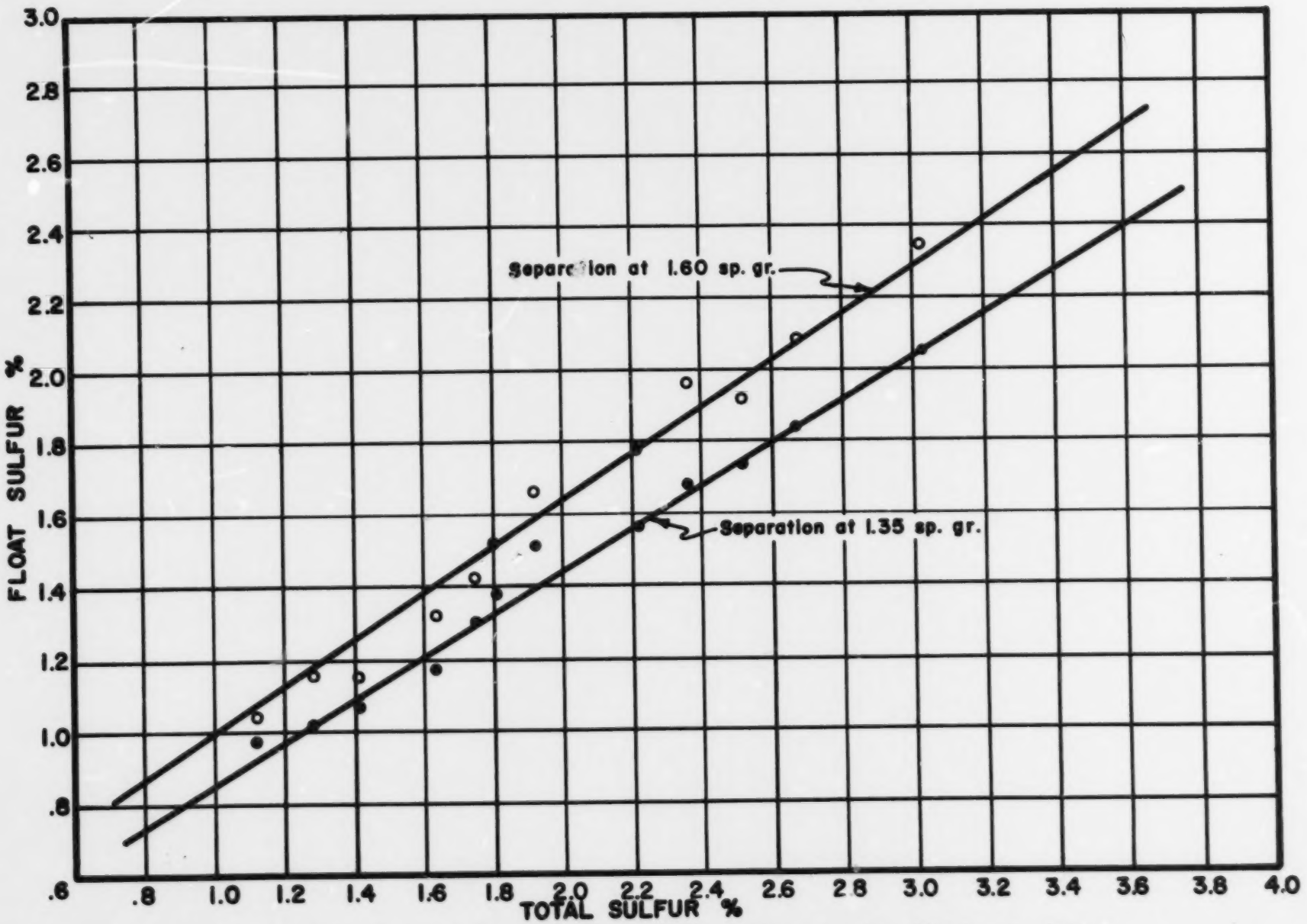
A

ounties, Where Pyrite Removal is Relatively Easy through Crushing and Washing

| Head Sulfur % | Sp. Gr. | 1 1/2" x 0 Yield | 1 1/2" x 0 Ash | 1 1/2" x 0 Sulfur | 3/8" x 0 Yield | 3/8" x 0 Ash | 3/8" x 0 Sulfur | 14 Mesh x 0 Yield | 14 Mesh x 0 Ash | 14 Mesh x 0 Sulfur |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.76 | 1.60 | 87.5 | 8.9 | 1.86 | 87.2 | 8.1 | 1.27 | 87.7 | 7.3 | 0.90 |
| 3.38 | 1.60 | 77.7 | 8.6 | 1.31 | 76.0 | 7.8 | 0.93 | 77.7 | 6.7 | 0.82 |
| 5.64 | 1.48 | 83.9 | 6.8 | 3.10 | 83.1 | 4.5 | 1.57 | - | - | - |
| 2.62 | 1.50 | 81.6 | 7.2 | 1.53 | 80.2 | 6.4 | 1.23 | 79.2 | 5.4 | 1.03 |
| 2.64 | 1.46 | 91.0 | 5.0 | 1.82 | 90.2 | 4.4 | 1.44 | 92.6 | 3.7 | 1.15 |
| 3.29 | 1.50 | 75.8 | 6.7 | 1.85 | 74.9 | 6.1 | 1.61 | 75.1 | 5.3 | 1.34 |
| 5.00 | 1.55 | 60.8 | 10.3 | 2.62 | 59.7 | 9.4 | 2.19 | 58.7 | 8.0 | 1.76 |
| 4.57 | 1.45 | 85.8 | 6.0 | 2.15 | 85.3 | 5.7 | 2.01 | 85.4 | 5.0 | 1.81 |
| 2.27 | 1.47 | 92.3 | 7.1 | 1.71 | 91.2 | 6.4 | 1.42 | 90.0 | 6.5 | 1.35 |

he Preparation Characteristics of Bituminous Coal Reserves in Pennsylvania with Special
No. SR-35, Oct. 1962, College of Mineral Industries, The Pennsylvania State University

B




Relation of Raw-Coal Sulfur to Float-Coal Sulfur in the Pittsburgh Bed
(Averages of Groups of Three Samples 3/8" x 14M.)

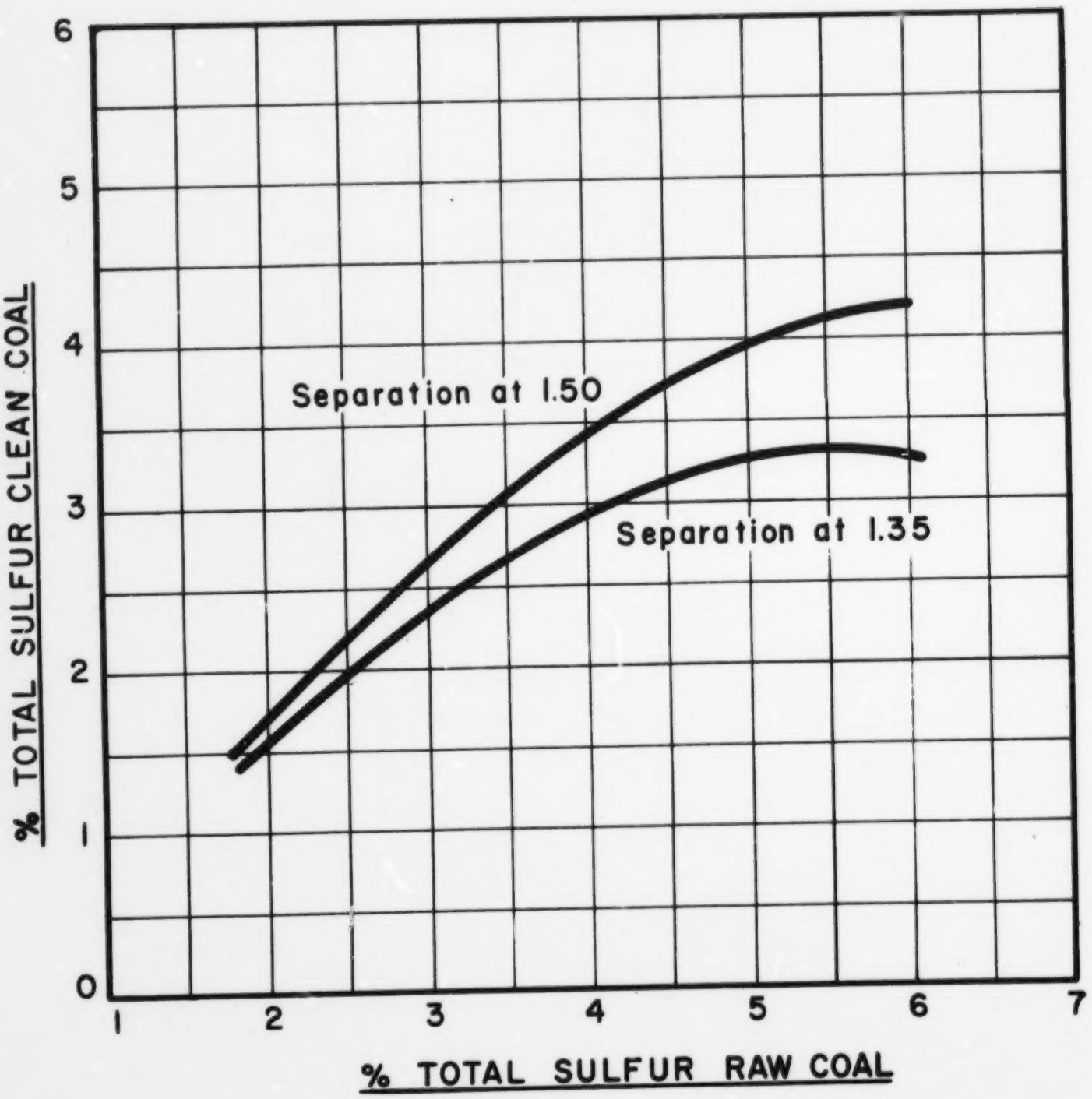
Reference: U.S. Bureau of Mines
Bulletin 483, 1950

Figure 11

Figure 12

Illinois No. 6 Bed Coal

Variation in Sulfur Reduction
at 1.35 and 1.50 Specific Gravities, Coal
Crushed to 1-1/2" x 0



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### 3.7.1 Special Studies of Fine Crushing of High Sulfur Coals

Special studies of stage crushing and grinding of some selected high sulfur coals have been obtained from several sources. It is unfortunate that similar data on all the important coal beds have not yet been made available.

Table No. 8 and Figure Nos. 13, 14, 15 and 16 summarize the float and sink analyses on a sample of the Pittsburgh bed, Panhandle District (6) of West Virginia, and the results of stage crushing and grinding down to 200 mesh.

The organic sulfur in this coal is 1.44 percent. The total sulfur in the raw coal is slightly over 4.0 percent. Crushing this coal to only minus 1-1/2 inches and floating at densities down to 1.30 gave a minimum sulfur of 2.50. By crushing in stages to 3/8 inches, 14 mesh, 30 mesh and finally 200 mesh (74 microns), a reduction to 1.80 percent sulfur was reached.

Using a 1.60 specific gravity, a normal separating density for steam coal, sulfur was 3.90 percent for the 1-1/2" x 0 coal and down to 1.96 percent for the 200 mesh x 0. At this separation a coal recovery or yield of 74.5 percent was obtained. The yield at 1.30 specific gravity is only 42.2 percent. It can be concluded that less than 2.00 percent sulfur cannot be achieved with this coal unless it is pulverized to minus 200 mesh.

Table No. 9 and Figure No. 17 show the effect of crushing Meigs Creek No. 9, Ohio bed from Noble County to two sizes, minus 2 inches and minus 30 mesh, with float and sink data on each of these sizes. This testing was made by the Ohio State University.

Here with a head sulfur content of 4.7 percent, the crushed 2" x 0 sulfur was reduced to 3.64 percent at 1.50 specific gravity and the lowest sulfur was 3.05 percent at 1.35 (with only a 32.8 percent yield of product).

Pulverizing down to 30 mesh reduced sulfur to 2.99 percent at 1.50 and 2.76 percent at 1.35. The coal yield at the latter specific gravity was only 41.1 percent.

The organic sulfur in this coal is 2.15 percent. On a pyritic basis only, crushing to 30 mesh liberated 68 percent of the sulfur at 1.50 and 78 percent at 1.35 specific gravity. Grinding this coal to even 200 mesh, one would still end up with coal over 2.00 percent sulfur.

Table No. 8

Effect on Sulfur Reduction by Crushing Run of Mine Coal

Pittsburgh Bed, Panhandle District (6), West Virginia

Float and Sink Analyses

| Specific Gravity Fractions | To 1 1/2" x 0 Cumulative Yield % | Sulfur % | To 3/8" x 0 Cumulative Yield % | Sulfur % | To 14 M x 0 Cumulative Yield % | Sulfur % | To 30 M x 0 Cumulative Yield % | Sulfur % | To 200 M x 0 Cumulative Yield % | Sulfur % |
|---|---|---|---|---|---|---|---|---|---|---|
| Float- 1.30 | 23.4 | 2.50 | 29.7 | 2.41 | 38.3 | 2.24 | 42.8 | 1.90 | 42.2 | 1.80 |
| 1.30 - 1.35 | 60.0 | 3.15 | 62.5 | 3.03 | 57.5 | 2.52 | 59.5 | 2.00 | 56.5 | 1.82 |
| 1.35 - 1.40 | 71.2 | 3.49 | 70.5 | 3.31 | 67.1 | 2.75 | 67.0 | 2.10 | 63.5 | 1.85 |
| 1.40 - 1.50 | 75.0 | 3.80 | 78.0 | 3.65 | 71.0 | 3.05 | 73.5 | 2.25 | 75.0 | 1.94 |
| 1.50 - 1.60 | 82.4 | 3.90 | 80.5 | 3.78 | 78.8 | 3.21 | 77.4 | 2.31 | 77.5 | 1.96 |
| Sink + 1.60 | 100.0 | 4.08 | 100.0 | 4.14 | 100.0 | 4.01 | 100.0 | 4.04 | 100.0 | 4.02 |

Note: Data Source: U.S.B.M. Private Communication

Deep Mine Coal. Head Ash 20.0 %. Total Sulfur 4.01 - 4.14

| Forms of Sulfur: Moisture Free | Sulfate | Organic | Pyritic |
|---|---|---|---|
| | 0.02 | 1.44 | 2.59 |

Slight variation in calculated head sulfurs are due to normal variations in sampling and testing procedures. Ash reductions in clean coal are substantial. For example at the 1.40 gravity point - 6.6, 6.2, 5.5, 4.2, 3.2 % Ash respectively, from 1 1/2" x 0 down to 200 Mesh x 0.

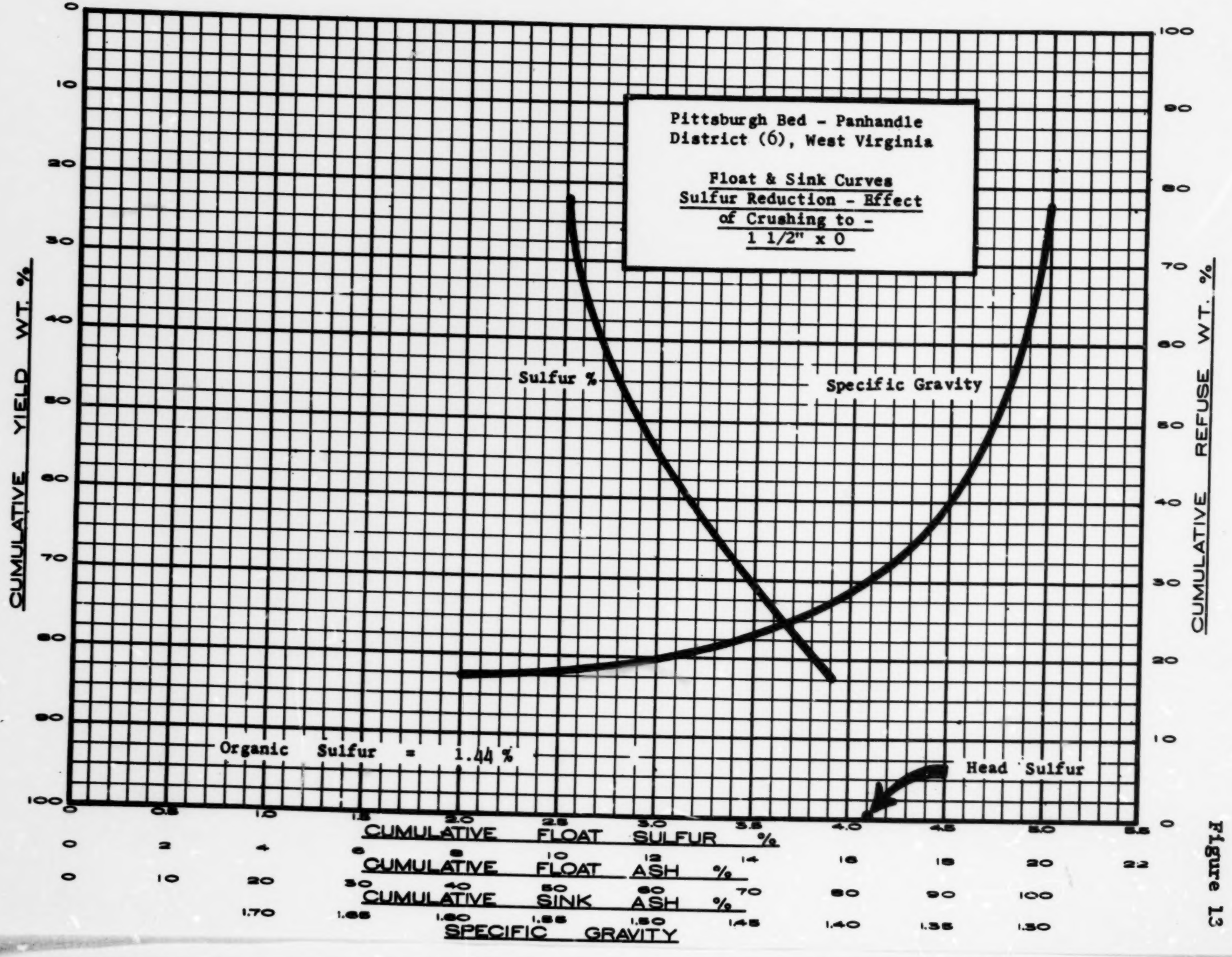
Pittsburgh Bed - Panhandle District (6), West Virginia
Float & Sink Curves
Sulfur Reduction - Effect of Crushing to -
1 1/2" x 0
Sulfur %
Specific Gravity
Organic Sulfur = 1.44 %
Head Sulfur
CUMULATIVE YIELD WT. %
CUMULATIVE REFUSE WT. %
CUMULATIVE FLOAT SULFUR %
CUMULATIVE FLOAT ASH %
CUMULATIVE SINK ASH %
SPECIFIC GRAVITY

Figure 13

Pittsburgh Bed - Panhandle
District (6), West Virginia

Float & Sink Curves
Sulfur Reduction - Effect
of Crushing to -
3/8" x 0

Sulfur %

Specific Gravity

Organic Sulfur = 1.44 %

Head Sulfur

CUMULATIVE YIELD WT. %

CUMULATIVE REFUSE WT. %

CUMULATIVE FLOAT SULFUR %

CUMULATIVE FLOAT ASH %

CUMULATIVE SINK ASH %

SPECIFIC GRAVITY

Figure 14

Pittsburgh Bed - Panhandle
District (6), West Virginia

Float & Sink Curves
Sulfur Reduction - Effect
of Crushing to -
1¼ Mesh x 0

CUMULATIVE YIELD WT. %

CUMULATIVE REFUSE WT. %

Sulfur %

Specific Gravity

Organic Sulfur = 1.44 %

Head Sulfur

CUMULATIVE FLOAT SULFUR %

CUMULATIVE FLOAT ASH %

CUMULATIVE SINK ASH %

SPECIFIC GRAVITY

Figure 15

Pittsburgh Bed - Panhandle
District (6), West Virginia

Float & Sink Curves
Sulfur Reduction - Effect
of Crushing to -
A- 30 Mesh x 0
B- 200 Mesh x 0

Cum. Sulfur Curves

Specific Gravity Curves

Organic Sulfur = 1.44%

Head Sulfur

CUMULATIVE YIELD WT. %

CUMULATIVE REFUSE WT. %

CUMULATIVE FLOAT SULFUR %

CUMULATIVE FLOAT ASH %

CUMULATIVE SINK ASH %

SPECIFIC GRAVITY

Figure 16

Table No. 9

Effect on Sulfur Reduction by Crushing Run of Mine Coal

Meigs Creek No. 9 - Ohio Bed, Noble County

Float & Sink Analysis

| Specific Gravity Fractions | To 2" x 0 Cumulative Yield % | To 2" x 0 Cumulative Sulfur % | To 30 Mesh x 0 Cumulative Yield % | To 30 Mesh x 0 Cumulative Sulfur % |
|---|---|---|---|---|
| Float - 1.30 | 1.4 | - | 15.1 | 2.58 |
| 1.30 - 1.35 | 32.8 | 3.05 | 41.1 | 2.76 |
| 1.35 - 1.40 | 59.7 | 3.32 | 55.9 | 2.85 |
| 1.40 - 1.45 | 71.9 | 3.50 | 65.3 | 2.93 |
| 1.45 - 1.50 | 78.6 | 3.64 | 70.7 | 2.99 |
| 1.50 - 1.55 | 82.1 | 3.76 | 74.6 | 3.05 |
| 1.55 - 1.70 | 87.8 | 3.97 | 81.3 | 3.18 |
| Sink + 1.70 | 100.0 | 4.79 | 100.0 | 4.79 |

Note:

Run of Mine: Head Ash 24.7 %, Sulfur 4.79 %
Organic Sulfur - 2.15 %
Clean Coal Ash at 1.45 is 9.0 %

Data Source: "The Meigs Creek No. 9 Bed in Ohio", by P. O. Krumin, Engr. Exper. Bul. No. 165, Vol. XXVI, No. 3, July 1957, Ohio State University

Table No. 9

Ohio Meigs Creek No. 9 -
Noble County
Float & Sink
Sulfur Reduction - Effect
of Crushing to
A- 2" x 0
B- 30 Mesh x 0

Cum. Sulfur Curves

Specific Gravity Curves

Head Sulfur

B

A

CUMULATIVE YIELD WT. %

CUMULATIVE REFUSE WT. %

0 10 20 30 40 50 60 70 80 90 100

0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5

CUMULATIVE FLOAT SULFUR %

0 2 4 6 8 10 12 14 16 18 20 22

CUMULATIVE FLOAT ASH %

0 10 20 30 40 50 60 70 80 90 100

CUMULATIVE SINK ASH %

1.70 1.65 1.60 1.55 1.50 1.45 1.40 1.35 1.30

SPECIFIC GRAVITY

Figure 17

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These two tests are the only complete studies of stage crushing to 30 mesh or 200 mesh made available to us on high sulfur coals. There are some similar data available on relatively low sulfur coals used for coking made by various steel companies.

The Bituminous Coal Research, Inc., is currently conducting a series of tests along these lines, in connection with their research on pulverization and separation of pyrite by air classification. In their paper by R. D. Harris, "Reducing the Sulfur Content of Steam Coal by Removing Fine Pyrite at the Power Station", they showed similar results with West Virginia Pittsburgh bed coal and Meigs Creek Ohio No. 9. They also show the results of pulverizing the Illinois No. 6 bed coal to 60 mesh and testing by float and sink at 1.60. With a head sulfur of 5.36 percent the lowest sulfur obtained was 3.11 percent. Organic sulfur in this coal was 2.25 percent.

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## SECTION 6.0 References

1. U.S. Bureau of Mines

   (a) All Technical Papers dealing with Coal Preparation and Coal Analyses.
   (b) All Information Circulars dealing with Coal Preparation and Coal Analyses.
   (c) All Bulletins dealing with Coal Preparation and Coal Analyses.
   (d) Unpublished data.
   (e) Reports of Investigations.
   (f) Minerals Year Books.
   (g) Mineral Industries Surveys, 1957-1963.

2. "Liberation of Pyrite from Steam Coals", by R. A. Glenn and R. D. Harris, Bituminous Coal Research, Inc., Monroeville, Pennsylvania, American Power Conference.

3. "Petrographic Composition and Sulfur Content of Pittsburgh Seam Coal", by the Coal Research Board, the Pennsylvania State University, Number SR-2, August, 1958.

4. "The Preparation Characteristics of the Bituminous Coal Reserves of Pennsylvania with Special Emphasis on Sulfur Reduction", the Coal Research Board, the Pennsylvania State University, SR-35, October, 1962.

5. "Reducing Sulfur Content of Steam Coal by Removing Fine Iron Pyrite at the Power Station", by R. D. Harris, AIME (SME), October 7-9, 1965, Bituminous Coal Research, Inc.

6. "Supplies, Costs and Uses of the Fossil Fuels", by the Energy Policy Staff, February, 1963, U.S. Department of the Interior.

7. "The Demineralization of Pulverized Upper Freeport Coal in a High-Intensity Magnetic Separator", by William M. Kester, Jr., SME (AIME), T.P. 65F68, February, 1965.

8. "New Dry Process for Coal Preparation", by A. Z. Yourovsky, et al, Fourth International Coal Preparation Congress, 1962.

9. "Removal of Sulfur from Fuels and Products of Combustion", by T. T. Frankenberg, December, 1964, ASME, New York.

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10. "The Meigs Creek No. 9 Coal Bed in Ohio", by P. O. Krumin, July, 1957, Ohio State University, Engr. Exper. Sta., Bulletin No. 165.

11. Illinois Geological Survey, Urbana, Illinois

All pertinent Bulletins and Technical Papers.

12. "National Power Survey", Federal Power Commission, Parts I and II, 1964.

13. Proceedings of the Energy Transportation Conference, St. Louis, Missouri, November, 1963.

14. "Steam Electric Power Plant Factors", National Coal Association, 1963.

15. Keystone Coal Buyers Manual, Mc-Graw-Hill, Inc., 1964.